MANUAL

OF

MILK PRODUCTS

BY

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PLATE I. — Laboratory for teaching the composition and methods of testing dairy products.

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PREFACE

THE annual value of dairy products in the United States is more than six hundred million dollars. The handling of these products makes an industry of great commercial and economic importance. The time is rapidly passing when people regard milk, butter, cheese, and ice cream as luxuries to be used chiefly to please the taste. Rather, they are now used because they furnish valuable food nutrients in desirable form. As the problem of feeding the cities becomes more acute and the food value of dairy products is more generally recognized, they will form a more important item in the human diet. The methods by which these products are handled influence decidedly their food value. It is, therefore, important that, in the handling of these products, the best practices should be employed. During recent years much has been added to our knowledge in this field and much has been written, but it is widely scattered through agricultural literature and is not easily accessible. This "Manual" has been prepared for the purpose of bringing together the work of the best authors into such form as to meet the needs of busy persons, both students and men in commercial work. The book is made up largely of quotations, credit being given in each case. No claim is made to originality, my task being rather that of selection and arrangement. If the book meets a need, an effort will be made to keep it up to date.

W. A. STOCKING.

ITHACA, N. Y., March, 1917.

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MANUAL OF MILK PRODUCTS

CHAPTER I

MILK SECRETION

MILK is the secretion of the mammary gland and is produced by the females of all species of mammals as food for their young. To the unaided eye milk appears as a yellowish white, somewhat viscous, opaque fluid, with homogeneous structure. In reality milk consists of a number of substances, some of which are in true solution while others are simply held in suspension. Cow's milk is nearly neutral in reaction and has a pleasant, sweetish taste.

THE PURPOSE OF MILK SECRETION (Bitting)

In reproduction among the higher animals, the offspring at birth are not sufficiently matured to be able to subsist alone; neither are they surrounded by food that is already prepared for them. It is therefore necessary that nature should provide for a part or whole dependence upon the mother for subsistence during such time as is required for development to a state capable of independent existence. As a means to this end, we find a mammary gland in a very large group of animals, the secretion of which is known as milk, and is a perfect food. Milk contains all the nutriment required by a growing body, in proper proportions, in a palatable and easily digestible form.

For these reasons persistent efforts have been made to domesticate animals and develop this function to the highest degree as a source of food for people.

Wild animals secrete only a sufficient quantity of milk to meet the needs of their young until they become sufficiently developed to secure their own food. Under the influence of domestication the functional activity of the gland has been greatly developed both in the quantity produced and in the duration of the period of lactation. Under domestication the cow in particular has been developed to produce a quantity sufficient to support several offspring and to keep up the secretion almost continuously.

PHYSIOLOGY OF THE MAMMARY GLAND (Bitting)

The mammary gland being an accessory organ of generation, it is but natural that it should be rudimentary at birth and without function. It remains in this condition until the reproductive function becomes active, at which time it begins to develop quite rapidly and continues to do so until the end of the first period of gestation. Like other organs of the body, it grows with the general growth and also from usage. Its functional activity does not ordinarily begin until near the close of the period of gestation, reaches its maximum at from ten to fifteen days thereafter, and then gradually declines and practically ceases in from six to ten months. If the gland should be examined at birth, a white fluid will be found in the ducts, but it is not true milk. True milk may occur, however, at a very early date and without the stimulus of pregnancy.

The male is possessed of a rudimentary mammary gland, which does not normally become active but which may produce a fluid closely resembling true milk.

The udder of the cow consists of two glands lying horizontally side by side and separated by a layer of tissues which helps to support them. The glands are distinct from each other, as

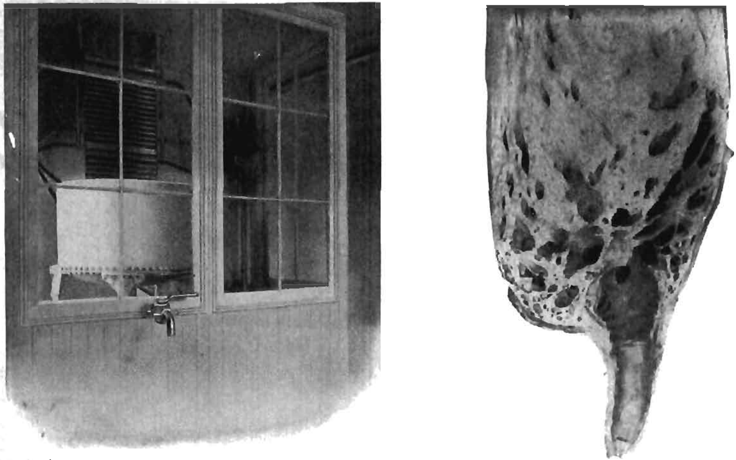


PLATE II. — Left, milk cooler protected against contamination by dust. See p. 157. Right, longitudinal section of a "quarter" of cow's udder, showing the milk cistern and larger ducts. See p. 3.

may be noted by examining the under side of the udder, where the furrow separating them will be found. Each gland ordinarily has two teats on its lower side through which the milk may be drawn from that particular gland. Each of the four teats draws the milk from what is usually termed a "quarter" of the udder. The two teats on the same side of the udder are from the same gland. As the glands are distinct from each other, so in a measure are the quarters. For example, it frequently occurs that cows have garget in one quarter while the other teat from the same gland milks freely and appears healthy.

If an udder be dissected, it appears somewhat spongy and pinkish, having numerous holes, or canals, much like a sponge. When cut, milk escapes from the incision. Within each teat is a cavity from which the milk is drawn. At the lower end of each teat a small muscle encircles the outlet to prevent the es-

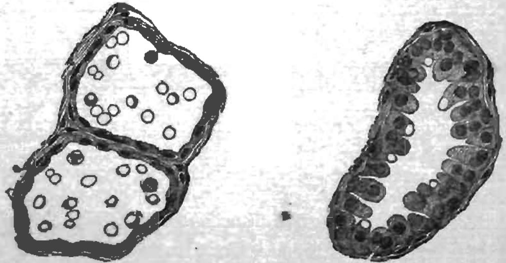


FIG. 1. — Section through alveoli of the mammary gland of the dog in first and second stages of secretion.

cape of the milk. Each of the glands of the udder is composed of a quantity of structure somewhat resembling a bunch of grapes. That which may be considered to represent the bunch is called the lobe; the lobule corresponds to one grape, and

the alveoli are smaller glands or ducts within the lobule. The alveoli are exceedingly small and can be seen only under a microscope of high power.

The actual secretion of the milk goes on in the alveoli. Exactly how the milk is secreted is not known.

THE ELABORATION OF MILK IN THE ANIMAL ORGANISM

Early theories.

"There has been a large number of theories advanced as to the methods by which milk is elaborated, most of them based upon the assumption that it is a comparatively simple chemical and physical problem. All the earlier theories were based upon such assumption, the physiologists regarding the mammary gland as an organ to separate certain elements from the blood in definite proportions as milk. It was regarded that the process was largely one of trausudation through a special membrane, on the same principle that exchange of gases by osmosis occurs rapidly in the tissues of the lungs. It was assumed that the fat of the food and the water and the salts taken into the alimentary canal were absorbed and taken into the blood and then eliminated by the mammary gland. The milk-serum was regarded as escaped blood serum, and that the other particles were derived from the blood or epithelial cells. The gland was assumed to be a semipassive organ, receiving the milk already prepared, and only requiring elimination in the proper proportions." — Bitting.

In order to test the accuracy of this theory, Jordan and Jenter[1] conducted a very careful experiment for the purpose of determining whether or not the fat in milk is derived from the fat in the food which the cow consumes. Analyses were made of the feeds and milk and the urine and fœces collected,

[1] New York Expt. Sta. Bul. 132.

in order to determine what became of the food the cow consumed. Their *conclusions are as follows:*

"A cow fed during ninety-five days on a ration from which the fats had been nearly all extracted, continued to secrete *milk similar to that produced when fed on the same kinds of* hay and grain in their normal condition.

"The yield of milk-fat during the ninety-five days was 62.9 lb. *The food fat eaten during this time* was *11.6 lb.,* 5.7 lb. only of which was digested, consequently at least 57.2 lb. of the milk-fat must have had some source other than the food fat.

"The milk-fat could not have come from previously stored body fat. This assertion is supported by three considerations: (1) The cow's body *could* have contained scarcely more than 60 lb. of fat at the beginning of the experiment; (2) she gained 47 pounds in body weight during this period of time with no increase of body nitrogen, and was judged to be a much fatter cow at the end; (3) the formation of this quantity of milk-fat from the body fat would have caused a marked condition of emaciation, which, because of an increase in the body weight, would have required the improbable increase in the body of 104 lb. of water and intestinal contents.

"During fifty-nine consecutive days 38.8 lb. of milk-fat was secreted and the urine nitrogen was equivalent to 33.3 lb. of protein. According to any accepted method of interpretation not over 17 lb. of fat could have been produced from this amount of metabolized protein.

"The quantity of milk solids secreted bore a definite relation neither to the digestible protein eaten nor to the extent of the protein metabolism.

"The composition of the milk bore no definite relation to the amount and kind of food.

"The changes in the proportion of milk solids were due almost wholly to changes in the percentage of fat."

The transudation theory fails to take account of the fact that the fats in the milk are unlike the fats in the food or body, and that casein and milk-sugar are not found in the blood or the mammary gland itself.

In discussing this theory, Armsby says, "The milk is not simply secreted from the blood like the urine in the kidneys, or the digestive juices in the stomach and intestines, but is formed in the milk glands from the cells of the gland itself — it is the liquefied organ. This is shown even by the composition of its ash, which, like that of all tissues, contains much potash and phosphate of lime, while the fluids of the animal body are poor in these substances and rich in chloride of sodium (common salt); the ash of milk contains three to five times as much potash as soda, while the ash of blood, on the other hand, contains three to five times as much soda as potash. Were the milk simply a transudate from the blood, it would have a similar composition, and could not serve as the exclusive food of the young animal, since it would not contain all the elements necessary for growth; but, since it is a liquefied organ, it is exactly adapted to build up other organs."

"Another theory that has had many supporters is that milk is the result of the separating of part of its constituents, as the water serum and salt from the blood, and part due to a fatty degeneration of the cells lining the alveolar cavities, the fat globules being due to the degenerated cells and the casein due to the undegenerated portion of the cells. This theory is actively supported by many of the best physiologists. Smith, after examining all the phases of milk secretion, sums up the whole as follows: 'The process of milk secretion may therefore be regarded as a process of metabolism of the epithelial cells, which undergo decomposition and discharge the resulting products into the excretory ducts.' He regards 'fat as a product of fatty degeneration of the protoplasmic cell contents, for it is not increased, but actually diminished, by an increase

of fat in the foods. On the other hand, an increase of proteids in the diet will cause an increase in milk-fat. In microscopic examination of the epithelial cells of the mammary gland, oil globules may be actually seen to increase in size and number until often the protoplasmic content becomes almost entirely replaced by oil globules which entirely agree in their characteristics with the oil globules found in milk.' In feeding animals on a highly albuminous diet they increase in weight and produce more fat in the milk, at the same time showing that they cannot be filling the pail from adipose tissue. However, in herbivora not enough albuminoids are being taken up to account for this fact, so that some must be derived from the blood." — Bitting.

Present theory of milk secretion (Bitting).

The *latest theory is to regard milk as a product of metabolism* of the cells of the mammary gland. It is in all essential characters a secretory product. In viewing the physiology of the formation of milk in such a light, it is only regarding it in the same way as saliva and gastric and pancreatic juices. It may be argued that these glands secrete a special product to be used in the animal economy, while milk is not so used. All excretory glands, as the kidneys, liver, and sweat glands, find their material already prepared in the blood, the result of activity in other parts of the body, and they serve as a means of eliminating it. Secretory glands, as the pancreas, salivary glands, and the like, do not find their active principles in the blood, but construct them within their own special cells. The mammary gland does not find fat, casein, and lactose in the blood, but constructs them within its own tissues. The recognition of the mammary gland as an organ having a special function will explain fully all the difficulties met in trying to reconcile all other theories with the facts as they are observed.

The theory of special cell metabolism is supported by the behavior of the gland viewed from an anatomical standpoint.

The cells differ when at rest and when active. When at rest the cells lining the alveoli lie flat and close to the wall. Their nuclei are small and spindle form. During a period of activity they are much enlarged, filling nearly the entire cavity, and the nuclei are prominent. The cells may be seen in all stages of reproduction, and in these particulars the gland shows the same characters as seen in the secreting glands already mentioned.

This theory is further sustained by the antecedents of the milk. When fat is taken into the intestine and assimilated it no longer has an existence as fat, but is broken up into various combinations. Fat as deposited in the body is not the same as the fat in the food. The proportions of olein and stearin have been changed to meet the peculiarity of the animal. Where the analytic and synthetic processes take place is not known. It is now recognized that it is not necessary that the fat in the body be derived from the fat of the food, but that the carbohydrates supply the necessary materials. With these proofs of synthetic process going on to produce body fat, it is not unreasonable to suppose that a similar process may take place in the formation of milk.

The milk-sugar, or lactose, is a product of metabolic activity of the protoplasm of the secreting cells of the mammary gland. This particular form of sugar occurs nowhere else in the body. It is a typical carbohydrate, and is found in the milk of animals fed exclusively upon meat, thus showing that the carbohydrates of the food are wholly unnecessary. Of all the constituents, the milk-sugar is least affected by external conditions.

The casein of milk is thought to be formed the same as the fat, although authorities differ on this point. The evidence seems to be in favor of this theory, for at the beginning and at the end of lactation the albumin, which is normally less than one-seventh of the casein, is actually in excess of it, and albumin is a normal constituent of both blood and milk. The proportion of casein in the milk is increased by greater perfection in

the activity of the cells. In the formation of colostrum, the albuminoid matter is greatly in excess of that after secretion is well established, and with the decrease of albumin there is a proportionate increase in casein. A ferment has been extracted from the mammary gland which will convert albumin into casein.

The water, no doubt, passes directly from the capillaries into the milk follicles, and carries with it the mineral constituents in solution.

The functions of the mammary gland are performed involuntarily. There seems to be some connection between the mammary gland and the central nervous system, but how much control can be exercised by will has not been determined. Locally the stimulus seems to be the empty milk duct, for when the ducts become full the secretion is partially checked, but is considerably stimulated during the process of milking.

RATE OF ACTIVITY IN MAMMARY GLAND (Bitting)

Collier made an investigation [1] to determine the number of fat globules found in milk in a given time. He made his observations on a large number of cows and found that on an average each secreted seven-tenths of a pound, or nearly 19.6 cubic inches, of milk an hour, and that there were 152 fat globules in each 0.0001 cubic inch of milk. He concluded that this was equivalent to secreting 136,000,000 fat globules a second. He duplicated his work on 23 other cows and found they secreted an average of 138,200,000 fat globules a second. Collier also recognized the fact that milk contains ingredients that must be the result of some special activity, as the casein and milk-sugar are not present in the blood and the fat only in traces, thus precluding the possibility of being derived by transudation. A good cow may produce 2.5 kilograms (5 lb.) of albu-

[1] New York State Experiment Station Report, 1891.

minoids, fat, and sugar. The weight of the total solids of a gland producing that amount of milk solids is only about 1.16 kilograms (2.25 lb.), which would necessitate a complete renewal of tissue 2.09 times a day. He might have added that the epithelial cells constitute only a small part of the gland structure, and it would therefore require even more rapid renewal. This would require an almost incredible cell growth, so that we are forced to assume that, although the growth and *disappearance of certain cells is of the greatest importance,* the organic substances in milk are modified from substances in the blood and lymph into the forms we find them in milk by the functional activity of the cells. The estimates upon the rate of cell multiplication as made by Collier are only approximate, but are certainly near enough to the truth to warrant drawing the conclusion that fat is not the result of fatty degeneration of the cells. In fact, such a process is incompatible with our knowledge of the physiology of the cell reproduction or disintegration.

FACTORS WHICH AFFECT MILK SECRETION

Since the function of milk secretion is the normal accompaniment of maternity, the mammary gland does not become fully developed or active until the time of parturition. At this time the blood which has been used to nourish the fœtus is turned into the arteries supplying the udder, and this increased flow of blood stimulates the action of the secretory cells. Bitting and Woods discuss the factors affecting milk secretion as follows:

"As milk is dependent upon the metabolism of the mammary gland, this is in turn dependent upon the quantity of blood passing through it. For large milking capacity it is necessary that there should be large glandular development; but, more important still, a large circulation of blood in the part. The cow must receive an ample supply of food and have the capacity

to eat, digest, assimilate, and turn into blood the elements necessary to form milk. Some time after parturition there is a tendency toward a shrinkage of the vessels of the udder, and this becomes more marked as the period of gestation advances. All the excess nutrition of the body is needed for the developing fœtus, and hence a lessening of the functional activity of the gland. That pregnancy is an influence tending to diminish milk secretion is demonstrated by the fact that spayed cows will continue to produce milk a long time, even from two to five years, during which time the quantity and quality make a very gradual decrease. While pregnancy has its influence upon the period of lactation, there are other factors that are of even greater importance and cannot be overlooked, the most important of which is the regularity and thoroughness of the emptying of the gland. If the milking process be done at irregular intervals, or incompletely, the activity of the gland soon ceases. Shortage of feed or water or disease may result in immediate cessation of secretion. The ordinary period of lactation is from nine to ten months throughout the life of the animal.

"The nervous system of the cow is closely associated with the production of the milk. When the teats are stimulated, either by the hands or the sucking of the calf, the nerves surrounding them become irritated, and through these the nerves of the secreting glands within the udder are excited, causing their contraction and the discharge of their contents. The action of the blood vessels and veins is affected by the activity of the nerves. Ordinarily the greater the capacity of the arteries and veins connected with the udder, the larger the milk secretion will be. This shows the importance of securing cows with a strong development of the arteries and veins of the udder and abdomen. An examination of the belly of a good dairy cow reveals thereon, extending from the udder along each side, a milk vein about one-half inch in diameter. The milk

veins at the point most distant from the udder pass through what are called the milk wells in the walls of the abdomen. These openings through which the veins pass should be of good size, so as to permit a strong flow of blood through them. As a rule, the greater the milk-secreting power of the cow, the larger and more twisted of outline will these veins be.

"While experts are able to judge from the general build of a cow much as to her capacity as a milker, the various rules, or 'points,' which have been laid down for judging the merits of milch cows are of themselves uncertain. While the form of the udder is important, as also the size of the milk vein, a large, well-formed udder is not always a sign of productiveness."

Beach[1] studied the effect of milking cows two and three times daily on the rate of secretion of milk and fat. In a study of eight cows he found that the percentage of fat was influenced by the frequency of milking. He reports his results as follows:

AVERAGE DAILY FAT YIELD OF EIGHT COWS

Name of Cow	Period I	Period II. Milked Three Times Daily				Period III
	Milked Twice Daily	5.15 A.M.	11 A.M.	4.45 P.M.	Total	Milked Twice Daily
	lb.	lb.	lb.	lb.	lb.	lb.
Olive	1.08	.495	.365	.495	1.355	1.079
Holstein	1.056	.479	.335	.498	1.312	1.008
Butterfly	.9301	.425	.485	.204	1.114	.911
Dolly D	1.173	.511	.330	.473	1.314	1.057
Black	1.209	.514	.495	.211	1.220	1.274
Black II	1.264	.547	.671	.219	1.437	1.251
Fairview	1.058	.543	.462	.168	1.173	1.223
Stella B	.751	.384	.291	.170	.845	.799
Average	1.065	.487	.427	.305	1.220	1.075
Total	8.523	3.898	3.434	2.438	9.770	8.602

[1] Storrs Annual Report, 1904.

The amount of milk and fat secreted an hour at different times in the twenty-four hours is not the same. The following table shows that the amount of milk secreted during the night in Period II was 1.041 lb. an hour and of fat .039 lb., while the amount secreted an hour up to noon was 1.23 lb. of milk and 0.74 lb. of fat.

It may be stated that the shorter the time between milkings, the larger the amount of milk and fat secreted an hour. This extra amount secured may be due in part to the additional manipulation of the udder by the hand of the milker as a result of additional milking, but the nervous condition of the cow is, no doubt, a factor.

In the table is given the amount of milk and fat secreted by each cow an hour when the cows were milked twice and three times a day. When milked twice a day, the amount of milk secreted an hour was .977 lb., and when milked three times, 1.10 lb. When milked twice, the amount of fat secreted was .0446 lb. an hour, and when milked three times, .056 lb. It will be noticed, however, that in the morning, after an interval of twelve and one-half hours, the amount of milk secreted an hour was 1.041; at 11 A.M., after an interval of five and three-fourths hours, the amount secreted was 1.23 lb.; and at 4.45 P.M., after an interval of five and three-fourths hours, the amount secreted was 1.12 lb. Similar variations appear in the secretion of fat. At the noon hour the percentage increase in the hourly secretion of milk and of fat, as compared with the hourly secretion when milked twice a day, was 26 per cent more milk and 66 per cent more fat. The percentage increase in the hourly secretion of fat up to the noon hour as compared with the morning hour was 89 per cent more fat, while the secretion of milk was only 18 per cent more. This difference is attributed by the writer to the nervous condition of the cow due to the unusual hour of milking. The average Babcock test of the cows at noou during the five days of Period II

was 7.1 per cent, 6 per cent, 6 per cent, 5.8 per cent, and 5.8 per cent.

AMOUNT OF MILK AND FAT SECRETED AN HOUR IN POUNDS

	Period I	Period II. Milked Three Times				Period III
	Milked Twice	5.15 A.M.	11 A.M.	4.45 P.M.	Aver.	Milked Twice
Milk	.977	1.041	1.23	1.12	1.10	.977
Fat	.0444	.039	.074	.053	.056	.0448

CHAPTER II

THE CHEMICAL COMPOSITION OF MILK

THE chemical composition of milk is very complex, being composed of the following constituents or groups of substances: (1) Water; (2) fats; (3) nitrogen compounds (casein and albumin); (4) milk-sugar; (5) mineral constituents or ash.

A few other substances occur in small quantities and will be discussed later, but they are present in such small amounts that they are not considered of much practical importance in the handling of milk or its products. The constituents of milk less the water are frequently grouped together as the milk solids or total solids, and the total solids without the fat are known as the solids not fat. The watery solution of all the solids except the fat is termed the milk serum. It is a viscous liquid with a whitish color.

The ingredients in milk vary more or less widely in percentage, being influenced by a number of factors or conditions. Therefore, no absolute figures can be given as representing the average composition, since any average which might be obtained will depend on the analyses of the individual samples from which each average is made. The best idea can be obtained from results by various workers, such as those given below representing averages from large numbers of individual analyses.

Richmond gives the average chemical composition of cow's milk in England as shown by about 280,000 analyses covering a period of seventeen years as follows:

AVERAGE CHEMICAL COMPOSITION OF MILK

	PER CENT		PER CENT
Water	87.35	Albumin	0.40
Fat	3.74	Ash	0.75
Milk-sugar	4.70	Other constituents	0.06
Casein	3.00		

The following data are taken from recent authorities in various countries as compiled by Wing:

	AMERICAN (Babcock)	ENGLISH (Oliver)	GERMAN (Fleischmann)	FRENCH (Cornevin)
Water	87.17	87.60	87.75	87.75
Fat	3.69	3.25	3.40	3.30
Casein	3.02	3.40	2.80	3.00
Albumin	.53	.45	.70	.40
Sugar	4.88	4.55	4.60	4.80
Ash	.71	.75	.75	.75
	100.00	100.00	100.00	100.00

AVERAGE COMPOSITION OF TYPICAL COW'S MILK (CONN. STA.)

AUTHORITY	TOTAL SOLIDS	FAT	SOLIDS NOT FAT	PER CENT OF FAT IN SOLIDS
English (Richmond, 1906)	12.70	3.73	8.97	29.37
(Richmond, 1907)	12.64	3.71	8.93	29.35
(Richmond, 1908)	12.69	3.75	8.94	29.56
(Vieth)	12.90	4.10	8.80	31.78
Canadian (McGill)	12.62	3.80	8.82	30.11
German (Koenig)	12.83	3.69	9.14	28.76
German (Fleischmann)	12.25	3.40	8.85	27.25
Dutch (Fleischmann)	12.00	3.25	8.75	27.08
American (Van Slyke)	12.90	3.90	9.00	30.23
(Van Slyke cheese factory)	12.60	3.75	8.85	29.76
(Voorhees, Ayrshire)	12.70	3.68	9.02	29.05
(Voorhees, Guernsey)	14.48	5.02	9.46	34.66
(Voorhees, Holstein)	12.12	3.51	8.61	28.96
(Voorhees, Jersey)	14.34	4.78	9.56	33.33
(Voorhees, Shorthorn)	12.45	3.65	8.80	29.32

AVERAGE ANALYSIS OF COW'S MILK (VAN SLYKE)[1]

	WATER	TOTAL SOLIDS	FAT	CASEIN	ALBUMIN	SUGAR	ASH
	per ct.	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*
Average of 5,552 American analyses compiled by the author . . .	87.1	12.9	3.9	2.5	0.7	5.1	0.7
Average cheese-factory milk for the season (May to Nov.) in N. Y. State . . .	87.4	12.6	3.75	2.45	0.7	5.0	0.7

Going into more detail regarding the solids in milk, Van Slyke and Bosworth say:

"It is difficult to learn what are the individual forms or compounds in which the salts exist in milk. Attempts have been made to determine this by inferences based on analytical results. . . . We suggest the following statement as representing in some respects more closely than previous ones, facts corresponding to our present knowledge of the principal constituents of milk. The amounts are based on milk of average composition.

Fat	3.90	per cent
Milk-sugar	4.90	per cent
Proteins combined with calcium	3.20	per cent
Di-calcium phosphate ($CaHPO_4$)	0.175	per cent
Calcium chloride ($CaCl_2$)	0.119	per cent
Mono-magnesium phosphate ($MgH_4P_2O_8$) .	0.103	per cent
Sodium citrate ($Na_3C_6H_5O_7$)	0.222	per cent
Potassium citrate ($K_3C_6H_5O_7$)	0.052	per cent
Di-potassium phosphate (K_2HPO_4) . . .	0.230	per cent
Total solids	12.901	per cent"

Since milk is the secretion of the mammary gland and is elaborated from the elements carried in the blood supply, it is

[1] Modern Methods of Listing Milk and Milk Products, Orange Judd Co.

to be expected that the milk of different species of mammals should be quite similar in composition. In general this is true, yet quite important variations are found, as will be seen from the following analyses of milk produced by different species:

AVERAGE COMPOSITION OF MILK OF VARIOUS KINDS (U. S. Dept. Agric.)

KIND OF MILK	WATER	TOTAL SOLIDS	PROTEIN			FAT	CARBO-HYDRATES (Milk-sugar)	MIN-ERAL MAT-TERS	FUEL VALUE PER POUND
			Casein	Albu-min	TOTAL				
	per ct.	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*
Woman .	87.58	12.6	0.80	1.21	2.01	3.74	6.37	0.30	310
Cow . .	87.27	12.8	2.88	0.51	3.39	3.68	4.94	0.72	310
Goat .	86.88	13.1	2.87	0.89	3.76	4.07	4.64	0.85	315
Sheep .	83.57	16.4	4.17	0.98	5.15	6.18	4.73	0.96	410
Buffalo (Indian)	82.16	—	4.26	0.46	—	7.51	4.77	0.84	—
Zebu .	86.13	—	—	—	3.03	4.80	5.34	0.70	—
Camel .	87.13	—	3.49	0.38	—	2.87	5.39	0.74	—
Llama .	86.55	—	3.00	0.90	—	3.15	5.60	0.80	—
Reindeer	67.20	—	8.38	1.51	—	17.09	2.82	1.49	—
Mare .	90.58	9.9	1.30	0.75	—	1.14	5.87	0.36	—
Ass . .	90.12	10.4	0.79	1.06	—	1.37	6.19	0.47	215

The mean composition together with the limits of variation found in various milks is given in the following table compiled by Leach from data given by Koenig:

	No. of Analyses	Specific Gravity	Water	Casein	Albumin	Total Proteids	Fat	Milk-sugar	Ash
Cow's milk	800								
Minimum		1.0264	80.32	1.79	0.25	2.07	1.67	2.11	0.35
Meximum		1.0370	90.32	6.29	1.44	6.40	6.47	6.12	1.21
Mean . .		1.0315	87.27	3.02	0.53	3.55	3.64	4.88	0.71
Human milk .	200								
Minimum		1.027	81.09	0.18	0.32	0.69	1.43	3.88	0.12
Maximum		1.032	91.40	1.96	2.36	4.70	6.83	8.34	1.90
Mean . .			87.41	1.03	1.26	2.29	3.78	6.21	0.31
Goat's milk	200								
Minimum		1.0280	82.02	2.44	0.78	—	3.10	3.26	0.39
Maximum		1.0360	90.16	3.94	2.01	—	7.55	5.77	1.06
Mean . .		1.0305	85.71	3.20	1.09	4.29	4.78	4.46	0.76
Ewe's milk	32								
Minimum		1.0298	74.47	3.59	0.83	—	2.81	2.76	0.13
Maximum		1.0385	87.02	5.69	1.77	—	9.80	7.95	1.72
Mean . .		1.0341	80.82	4.97	1.55	6.52	6.86	4.91	0.89
Mare's milk .	47								
Mean . .		1.0347	90.78	1.24	0.75	1.99	1.21	5.67	0.35
Ass's milk	5								
Mean . .		1.036	89.64	0.67	1.55	2.22	1.64	5.99	0.51

VARIATIONS IN NORMAL COW'S MILK

While the composition of milk is quite stable, all the constituents are more or less variable — even in normal milks. Koenig gives the following variations of the different constituents based on his study of several hundred samples collected from many sources.

Average Variation in Constituents of Cow's Milk
(Koenig)

	Maximum	Minimum
Water	90.69	80.32
Fat	6.47	1.67
Casein	4.23	1.79
Albumin	1.44	.25
Sugar	6.03	2.11
Ash	1.21	.35

Farrington and Woll give the following statement showing the limits within which the components of normal American cow's milk are likely to come:

	MINIMUM	MAXIMUM	AVERAGE
	per ct.	*per ct.*	*per ct.*
Water	82.0	90.0	87.4
Fat	2.3	7.8	3.7
Casein and albumin	2.5	4.6	3.2
Milk-sugar	3.5	6.0	5.0
Ash	0.6	0.9	0.7

WATER-CONTENT OF MILK

The water present in milk constitutes its most abundant constituent. In it all the other substances are held in solution or suspension, as the case may be. The water also serves to dilute the solid elements to the proper strength for the nourishment of the young calf. The water found in milk is the usual compound of oxygen and hydrogen commonly recognized as water, and its composition does not vary from the usual form in which it is found in nature.

THE FATS OF MILK

The composition of milk-fat (Van Slyke).[1]

Milk-fat, also called butter-fat, is not a single chemical compound, but is a somewhat variable mixture of several different compounds called glycerides. In this respect it differs from all other fats. Each glyceride is formed by the chemical union of glycerin as a base with some acid or acids of a particular kind. These glycerin-acid compounds, or glycerides, of milk-fat contain about ten different acids, some being present in small proportions. The four following acids enter most largely into the composition of milk-fat, in the form of their combina-

[1] **Modern Methods of Testing Milk and Milk Products, Orange Judd Co.**

tions with glycerin: Palmitic acid, oleic acid, myristic acid, and butyric acid. The compounds or glycerides, formed by the combination of glycerin and the acids, have special names derived from the acids; thus, we have palmitin (glycerin combined with palmitic acid), butyrin (glycerin combined with butyric acid), olein, etc. Milk-fat contains, on an average, about 40 per cent of palmitin, 34 per cent of olein, 10 per cent of myristin, 6 per cent of butyrin, and from less than 1 to nearly 3 per cent of each of the glycerides of other acids. Milk-fat contains about 12.5 per cent of glycerin in combination with the acids. The proportions of these constituents of milk-fat vary somewhat, and this variation influences the character of the milk-fat. Thus, palmitin and myristin tend to make milk-fat harder, while olein and butyrin have the opposite tendency.

The acids contained in milk-fat or butter-fat may be divided into two groups: (1) The acids in one group (palmitic, oleic, myristic, stearic, lauric) are insoluble in water and non-volatile, while (2) the other acids (butyric, caproic, etc.), are more or less completely soluble in water and are volatile. These differences afford a practical basis for distinguishing pure butter from artificial butter. Of the fat-acids contained in butter-fat, about 87.5 per cent consists of the insoluble fat-acids, while in other forms of animal fat (beef-fat, lard, etc.) the amount of these insoluble fat-acids is considerably greater. The amount of volatile fat-acids in milk-fat or butter-fat is much greater than in other forms of animal fat.

Table Showing the Composition of Milk-fat (Babcock)

Butter-fat 3.6%	Olein Palmitin Stearin Myristin Butin (trace)	Glycerides of insoluble and non-volatile acids	3.3	Fat 3.6
	Butyrin Caproin Caprylin (trace) Caprinin (trace)	Glycerides of soluble and volatile acids	0.3	

Browne gives the composition of milk-fat as follows with the percentage of each of the fatty acids:

Fatty Acid	Per Cent of Total Fat
Oleic	33.95
Palmitic	40.51
Myristic	10.44
Stearic	1.91
Dioxystearic	1.04
Butyric	6.23
Lauric	2.73
Caproic	2.32
Caprylic	0.53
Capric	0.34
	100.00

The non-volatile fats.

It will be seen that the non-volatile or insoluble fats constitute by far the greater part of the total fat in milk, possibly varying between the limits of from 85 to 88 per cent of the total. These fat-acids differ materially in their hardness or the temperature at which they melt. Richmond gives the melting point for the members of this group as follows:

Oleic	14.0° C.
Stearic	68.5 to 69.2
Palmitic	62.0
Myristic	53.8

The relative amounts of these fats are more or less variable, and have a decided effect on the texture of butter.

The volatile fats.

The volatile or soluble fats constitute only a small part of the total fats in milk, normally from 12 to 15 per cent. Of these, butyrin is present in the largest amounts. Like the non-volatile fat-acids, the members of this group also vary decidedly in their melting points which are given by Richmond as follows:

Butyric	2° C.
Caproic	1.5
Caprylic	16.5
Capric	30.0
Lauric[1]	43.6

It is from this group of fatty acids that dairy products derive many of their characteristic odors and flavors. Coming from the feed which the cows eat, these volatile substances rapidly pass through the body tissues during the process of digestion and assimilation and find their way into the milk and other secretions. They are rapidly eliminated from the animal body through the excretory organs, and within a short time after digestion is complete, they entirely disappear. Dairymen take advantage of this fact by not allowing the cows to eat aromatic foods such as onions, cabbage, and the like, for several hours before milking time. Butyrin is the principal volatile fat which imparts these odors and flavors to milk and its products.

THE SERUM OF MILK

As previously stated, the constituents of milk minus the fat are termed the milk-serum. The serum contains the substances of which nitrogen forms an element, commonly termed the proteids or albuminoids, the sugar or lactose, and the mineral element or ash, and the water. Babcock gives the following composition for milk-serum in percentage of the entire milk: Nitrogen compounds 3.8 per cent; milk-sugar 4.5 per cent; citric acid 0.1 per cent; ash 0.7 per cent; water 87.3 per cent.

The proteids or albuminoids

In this group are all those substanees which contain nitrogen. Babcock gives the following substances as constituting the proteids of milk: Casein 3.0 per cent; albumin 0.6 per cent;

[1] Van Slyke places this in the insoluble group.

lactoglobulin, galactin, fibrin (trace), 0.2 per cent; total 3.8 per cent.

Casein.

This is the most abundant of the albuminoids. It forms about 3 per cent of normal cow's milk and about 80 per cent of the proteins. Kirchner gives the percentage composition of casein as carbon 53.0; hydrogen 7.12; nitrogen 15.65; oxygen 22.6; sulfur 0.78, phosphorus 0.85. Casein occurs in milk in suspension, is insoluble in water, but is soluble in dilute alkalies and in strong acids and can be separated from the soluble constituents of milk-serum by means of a porous porcelain filter. Pure casein is a white, odorless, tasteless substance, and is the chief constituent in milk curd. It is coagulated by acid, as in the case of souring milk, or by rennet, as in the making of cheese.

Albumin or lact-albumin.

Normal milk contains about 0.6 per cent of albumin which forms about 15 per cent of the total proteids. It resembles the albumin of eggs and that found in the blood; is soluble in water and is not coagulated by dilute acids or rennet, but is coagulated by temperatures of 70–75° C.

Lactoglobulin.

This is a protein which occurs in normal cow's milk only in traces, but may be much more abundant in colostrum. It appears to be the same as the globulin in blood-serum, being coagulated by temperatures of 67–76° C. Lactoglobulin occurs in milk partly in solution and partly in suspension or colloidal solution.

Galactin.

This substance has been found by different workers to exist in milk in amounts approximating 0.1 per cent. Richmond says, "This is essentially lacto-protein, perhaps contaminated with some organic salts, and has no real existence in milk, being portions of the casein and albumin which had escaped

conditions which are opposed to the coagulation of fibrin being the ones which give the most efficient creaming.

The average amount of fibrin in milk is supposed to be about three ten-thousandths of one per cent, which is about one-thousandth as much as is found in blood. The amount in different milks varies considerably, some milks being almost free while others contain a large amount. Colostrum milk always contains more than normal milk from which it is derived, and skim milk contains scarcely any. This results from the fat globules being entangled in the small clots formed. The clots are thus floated and become incorporated with the cream.

Babcock did not actually demonstrate the presence of fibrin in milk, but Doane found "that where any inflammation of the udder exists, fibrin and white blood cells are given off, and this fibrin can be centrifuged out of the milk and smeared on a coverglass, and stained so that the threads are easily demonstrated by the use of a microscope. When this inflammation existed the fibrin could be seen as a large number or mass of parallel threads, and was associated with a vast number of leucocytes. It was noticed in looking for fibrin, in the sediment of milk, with a particularly small leucocyte count, that an occasional single fibrin thread would be seen. They were very few in number, and it was seldom that more than one thread could be seen in one microscopic field. They were so evidently like the threads found in the pus in all their characteristics that there was no reason for doubting that they were fibrin.

"The presence of the fibrin could not always be demonstrated in the known healthy milk by centrifuging. Two other means of securing it were tried. One was to allow the cream to rise on the milk, on the theory that a large part of the fibrin would be carried into the cream by the fat globules. A small portion of the cream was poured on several layers of filter paper, to

absorb as much of the milk-serum as possible. The resulting layer of fat was then scraped from the filter paper, and washed in a beaker with ether to dissolve the fat. This was then filtered, and the residue smeared on coverslips, stained with carbolized hematoxylin and then with eosin. A few fibrin threads were demonstrated in this manner.

"Another plan was to filter the milk through a hardened filter. This filter resembles parchment and is designed to stand suction. Milk filters very slowly by this means, and there can be little doubt that any fibrin threads are retained. The resultant filtrate was scraped into a beaker, washed with ether, filtered again, and the filtrate smeared on coverslips, and stained in the usual way. This method worked very satisfactorily in most instances, and the fibrin threads were easily demonstrated. This work should confirm Babcock's fibrin theory."

Milk-sugar

Cow's milk normally contains between 4 and 6 per cent of milk-sugar or lactose in solution in the milk-serum. Its chemical composition is the same as cane-sugar, $C_{12}H_{22}O_{11} + H_2O$, but it does not readily dissolve in water and therefore is not as sweet to the taste as is cane-sugar; 1 part of milk-sugar will dissolve in 6 parts of cold water or $2\frac{1}{2}$ parts of boiling water. Its specific gravity is 1.525. It is of considerable commercial value and is much used in the preparation of modified milk for infant feeding. Lactose is readily broken up by the action of lactic acid bacteria, one molecule of the sugar forming four molecules of lactic acid. This fermentation normally begins soon after the milk is drawn from the cow and, unless it is checked, goes on rapidly until enough sugar has been changed to acid to coagulate the milk. As the lactic acid accumulates in the milk, it reacts upon the activity of the bacteria, which practically cease their action when the acidity has reached

.8 to 1.0 per cent and no more sugar is broken down. Milk-sugar is commonly made from whey in connection with cheese-making.

Citric acid

Small amounts of citric acid have been found in milk. According to Babcock there is about 0.1 per cent in normal milk.

The mineral constituents or ash

The mineral elements in milk are very small in amount and less variable than most of the other constituents, constituting approximately three-fourths of 1 per cent of the entire milk. Because of the difficulty of determining accurately the amounts and the form in which these substances exist in milk, the data given by various investigators differ somewhat. The following represents our present knowledge as to the kinds and amounts of mineral substances in milk:

MINERAL ELEMENTS IN COW'S MILK EXPRESSED IN PER CENT (Babcock)

Ash	0.7%	Potassium oxide	0.175
		Sodium oxide	0.070
		Calcium oxide	0.140
		Magnesium oxide	0.017
		Iron oxide	0.001
		Sulfur trioxide	0.027
		Phosphoric pentoxide	0.170
		Chlorine	0.100

Leach says, "The ash of milk does not truly represent the mineral content, since, in the process of incineration, the character of some of the constituents is altered by oxidation and otherwise.

"Expressed in parts to 100, the ash of the typical milk sample would be about as follows:

Potassium oxide	25.02
Sodium oxide	10.01
Calcium oxide	20.01
Magnesium oxide	2.42
Iron oxide	0.13
Sulfur trioxide	3.84
Phosphoric pentoxide	24.29
Chlorine	14.28"

Söldner considers that the following more nearly represents the mineral constituents as they exist in cow's milk:

Sodium chloride, $NaCl$	10.62
Potassium chloride, KCl	9.16
Mono-potassium phosphate, KH_2PO_4	12.77
Di-potassium phosphate, K_2HPO_4	9.22
Potassium citrate, $K_3(C_6H_5O_7)_2$	5.47
Di-magnesium phosphate, $MgHPO_4$	3.71
Magnesium citrate, $Mg_3(C_6H_5O_7)_2$	4.05
Di-calcium phosphate, $CaHPO_4$	7.42
Tri-calcium phosphate, $Ca_3(PO_4)_2$	8.90
Calcium citrate, $Ca_3(C_6H_5O_7)_2$	23.55
Lime, combined with proteins	5.13

Other constituents of milk

Minute quantities of urea, lecithin, iodine, acetic acid, carbon dioxide, and other gases have been reported as existing in milk, but they are present only in traces and are probably of little practical significance.

Condition of casein and salts in milk (Van Slyke and Bosworth)

The chemistry of milk has been studied by many investigators. Numerous facts have been accumulated relating to the amounts and properties of the more prominent constituents of milk, including various conditions affecting the composition; but much less attention has been given to thorough study of individual constituents, owing largely to the difficulties involved in making such investigations. . . .

That portion of the milk consisting of water and the compounds in solution is known as the milk-serum. In studying the individual constituents of milk, it is necessary to separate the serum. Various methods have been used to separate milk-serum from the other constituents of milk, but the one best adapted for investigational purposes depends upon the fact that when milk is brought into contact with a porous earthenware filter, the water passes through, carrying with it the compounds in true solution, while the compounds insoluble in water or in suspension remain on the surface of the filter. We have made use of the special form of apparatus designed by Briggs[1] for the purpose of obtaining water-extracts from soils. Briefly stated, the process consists in putting the milk to be examined into a tubular chamber surrounding a Pasteur-Chamberland filtering tube; pressure, amounting to 40 to 45 pounds a square inch, is applied by means of a pump which forces air into the chamber containing the milk and causes the soluble portion of the milk to pass through the walls of the filter from the outside to the inside of the filtering tube, from which it runs out and is caught in a flask standing underneath. The insoluble residue accumulates on the outside surface of the filter tube from which it can easily be removed by light scraping.

Before being placed in the apparatus for filtration, the milk is treated with some antiseptic to prevent souring during the process of filtration.

The composition of the solid portion of milk removed by the filtering tube is ascertained by difference; from the figures obtained by an analysis of the original milk we subtract the results of analysis given by the serum.

[1] U. S. Dept. Agr. Soils. Bul. 19, p. 31, and Bul. 31, pp. 12–16.

Properties and composition of milk-serum (Van Slyke and Bosworth)

Serum prepared from fresh milk by the method described above has a characteristic appearance, being of a yellow color with a faint greenish tinge and slight opalescence.

The serum from fresh milk gives a slight acid reaction to phenolphthalein and a strongly alkaline reaction to methyl orange.

CONSTITUENTS OF MILK-SERUM

Constituents	Sample No. 1			Sample No. 2		
	Original Milk 100 C.C.	Milk-serum 100 C.C.	Percentage of Milk Constituents in Serum	Original Milk 100 C.C.	Milk-serum 100 C.C.	Percentage of Milk Constituents in Serum
	grams	*grams*	*per ct.*	*grams*	*grams*	*per ct.*
Sugar	—	—	—	5.75	5.75	100.00
Casein	3.35	0.00	0.00	3.07	0.00	0.00
Albumin	0.525	0.369	70.29	0.506	0.188	37.15
Nitrogen in other compounds	—	—	—	0.049	0.049	100.00
Citric acid	—	—	—	0.237	0.237	100.00
Phosphorus (organic and inorganic)	0.125	0.067	53.60	—	—	—
Phosphorus (inorganic)	0.096	0.067	70.00	0.087	0.056	64.40
Calcium	0.128	0.045	35.16	0.144	0.048	33.33
Magnesium	0.012	0.009	75.00	0.013	0.007	53.85
Potassium } Sodium }	[1] 0.354	[1] 0.352	99.44	0.120	0.124	100.00
				0.055	0.057	100.00
Chlorine	0.081	0.082	100.00	0.076	0.081	100.00
Ash	—	—	—	0.725	0.400	55.17

In the table above we give the results of the examination of two samples of fresh milk, the serum of which was prepared in the manner already described. These samples of milk

[1] As chlorides.

were treated with chloroform at the rate of 50 c.c. to 1000 c.c. of milk and the fat removed by means of a centrifugal machine; the removal of fat is necessary, since it clogs the pores of the filter. The fat-free milk was then filtered through Pasteur-Chamberland filtering tubes. Analyses were made of the milk and of the serum. We did not determine those constituents present in milk in traces only, such as iron, sulfuric acid, and so on.

A study of the data contained in the table enables us to show the general relation of the constituents of milk to the constituents of milk-serum. The following form of statement furnishes a clear summary of the facts:

1. Milk Constituents in True Solution in Milk-serum:	2. Milk Constituents Partly in Solution and Partly, in Suspension or Colloidal Solution:	3. Milk Constituents Entirely in Suspension or Colloidal Solution:
(*a*) Sugar	(*a*) Albumin	(*a*) Fat
(*b*) Citric acid	(*b*) Inorganic phosphates	(*b*) Casein
(*c*) Potassium	(*c*) Calcium	
(*d*) Sodium	(*d*) Magnesium	
(*e*) Chlorine		

The behavior of milk albumin attracts special attention on account of marked lack of regularity in the results obtained. We commonly think of milk albumin as readily and completely soluble in water, and the question is therefore raised as to why a considerable portion of it does not pass through the Pasteur-Chamberland filter. In view of all the facts available, the most probable explanation that has so far suggested itself is that in fresh milk a part of the albumin is held by the adsorbing power of casein. This suggestion is supported by results obtained in the following experiments: Serum was prepared from chloroformed fresh milk treated in different ways. In the first experiment, serum direct from the fresh milk was

compared with serum obtained from whey which had been obtained from another portion of the same milk by treatment with rennet-extract. In the second experiment, serum direct from fresh milk was compared with (*a*) serum obtained from another portion of the same milk after souring, and (*b*) serum obtained from another portion of the same milk to which some formaldehyde solution had been added. Albumin was determined in each case by boiling after addition of acetic acid, following the details given in the provisional method of the Association of Official Agricultural Chemists. The results of the experiments are given below.

FIRST EXPERIMENT	ALBUMIN PER 100 C.C.	ALBUMIN OF MILK RECOVERED IN SERUM
	grams	*per ct.*
Fresh milk	0.312	—
Serum from fresh milk . . .	0.143	45.83
Serum from whey	0.187	59.94
SECOND EXPERIMENT		
Fresh milk	0.266	—
Serum from fresh milk . . .	0.148	55.64
Serum from sour milk . . .	0.253	95.11
Serum from milk plus formaldehyde	0.245	92.21

In the first experiment it is seen that when casein is precipitated by rennet solution the curd (the precipitated casein or para-casein) carries down part of the albumin with it; the amount thus carried down is approximately equal in this case to that retained along with the casein on the external surface of the Pasteur-Chamberland filtering tube, when whole milk is filtered through such a filter.

In the second experiment we see that when the casein is precipitated with acid, as in the case of natural souring, the ad-

sorbing action of the casein is practically prevented and little or no albumin is carried down with it. In the case of the addition of formaldehyde to milk, the adsorbing power of casein is greatly diminished, probably due to the chemical reaction between casein and formaldehyde.

Properties and composition of that part of milk in suspension or colloidal solution (Van Slyke and Bosworth)

Some of the constituents of milk are suspended in the form of solid particles in such an extremely fine state of division that they pass through the pores of filter paper and they do not settle as a sediment on standing, but remain permanently afloat. They cannot be seen except by ultra-microscopic methods. When substances are in such a condition, they are said to form a colloidal solution. In passing milk through the Pasteur-Chamberland filtering tube, the constituents in suspension as solid particles, and in colloidal solution, are retained in a solid mass on the outside of the tube and can therefore be readily obtained for study.

Appearance.

When prepared by the method of filtration previously described, the insoluble portion of milk collecting on the outside of the filtering tube is grayish to greenish white in color, of a glistening, slime-like appearance and gelatinous consistency. When dried without purification by treatment with alcohol, and the like, it resembles in appearance dried white of egg.

Behavior with water.

The deposit of insoluble milk-constituents on the outside of the filtering tube, when removed and shaken vigorously in a flask with distilled water, goes into suspension and the mixture has the opaque, white appearance of the original milk. The deposit is, of course, more or less mixed with adhering soluble constituents but can be readily purified by shaking

with distilled water and filtering several times. The purified material goes readily into suspension on shaking with water and, if treated with a preservative, will remain indefinitely without change other than the separation of fat-globules. It has been held by some that the citrates of milk perform the function of holding the insoluble phosphates in suspension, but this is not supported by the behavior of the insoluble portion shown in our experiments.

Reaction.

A suspension of the insoluble constituents of milk, prepared in the manner described above, is neutral to phenolphthalein. We purified the deposit made from 1000 c.c. of milk, made a suspension of it in water, and, after the addition of 10 c.c. of neutral solution of potassium oxalate, it was found to require only 0.5 c.c. of $\frac{N}{10}$ solution of sodium hydroxide to make it neutral to phenolphthalein. We interpret this to mean that there are no tri-basic (alkaline) phosphates in milk or in the serum, because the serum, since it is acid, can contain none, and the insoluble portion, being neutral, can therefore contain none.

Relation of inorganic constituents to casein in milk.

Without going into a detailed discussion of the history of the different views held by different investigators, it is sufficient for our purpose to state that three general views have been put forward in regard to the relation of inorganic constituents to casein in milk: (1) That milk-casein is combined with calcium (about 1.07 per cent) to form a salt, calcium caseinate (which is neutral to litmus and acid to phenolphthalein); (2) that casein is chemically combined directly with calcium phosphate; (3) that casein is a double compound consisting of calcium caseinate combined with calcium phosphate.

We have attempted to learn what is the true condition of casein in milk in relation to inorganic constituents, whether it

is in combination with calcium alone or with some other inorganic base in addition, and also whether milk-casein is an acid salt or a neutral salt and, further, whether the insoluble phosphates are in combination with casein or not.

The authors summarize the results of their extended studies on this subject as follows:

1. Milk contains two general classes of compounds, those in true solution and those in suspension, or insoluble. These two portions can be separated for study by filtering the milk through a porous earthenware filter like the Pasteur-Chamberland filtering tube.

2. Serum prepared from fresh milk is yellow with a faint greenish tinge and slight opalescence. The following constituents of milk are wholly in solution in the milk-serum: sugar, citric acid, potassium, sodium, and chlorine. The following are partly in solution and partly in suspension: Albumin, inorganic phosphates, calcium, magnesium. Albumin in fresh milk appears to be adsorbed to a considerable extent by casein, and therefore only a part of it appears in the serum. In serum from sour milk and milk to which formaldehyde has been added, nearly all of the albumin appears in the serum.

3. The insoluble portion of milk separated by filtration through the Pasteur-Chamberland filtering tube is grayish to greenish white in color, of a glistening, slime-like appearance and gelatinous consistency. When shaken with water it goes readily into suspension, forming a mixture having the opaque, white appearance of milk. Such a suspension is neutral to phenolphthalein. When purified, the insoluble portion consists of neutral calcium caseinate (casein Ca_4) and neutral di-calcium phosphate ($CaHPO_4$). The casein and di-calcium phosphate are not in combination, as shown by a study of 16 samples of milk from 13 individual cows, and also by a study of the deposit or "separator slime" formed by whirling milk in a cream separator. By treating fresh milk with formalde-

hyde and whirling in a centrifugal machine under specified conditions, it is possible to effect a nearly complete separation of phosphates from casein.

4. The data presented, with results of other work, furnish a basis for suggesting an arrangement of the individual compounds contained in milk, especially including the salts.

COLOSTRUM (Hills)

Immediately after a birth and preceding the true milk flow, the mammary glands of the mother secrete an acrid, viscid, yellowish fluid, heavier than milk and of alkaline reaction, which is called the colostrum.

The first fluid given is most markedly colostral in character, the second and succeeding ones less so, until by the sixth to the tenth milking, the true milk flow is usually considered established and the product used.

Colostrum differs from milk mainly in containing less casein and sugar, more ash, many times more albumin, and in containing peculiar granules known as "colostrum corpuscles"; its office is purgative, enabling the offspring to rid itself of the accumulations of the fœtal bowel.

The following table gives the average composition of the colostrums of the three cows, analyses being grouped by milkings, and the average composition of milk three weeks later. The colostrum analyses are the means of three samples, and each milk, the mean of twelve. None of these first colostrums analyzed so high as they would have done had the cow been milked immediately after calving.

German analyses give as a maximum of twenty-two cows, milked immediately after calving, specific gravity 1.079, total solids 32.57, fat 4.65, casein 7.14, albumin 20.21, milk-sugar 3.83, ash 2.31.

Average Analyses	Specific Gravity	Total Solids Actual	Total Solids Calculated	Fat	Casein and Albumin	Milk-sugar	Ash
First milking colostrum . . .	1.0533	19.37	17.96	3.86	11.44	2.40	1.67
Second milking colostrum . .	1.0415	14.33	13.88	2.92	6.49	3.60	1.33
Third milking colostrum . .	1.0380	12.98	12.60	2.58	5.01	4.16	1.23
Fourth milking colostrum . .	1.0364	13.92	13.55	3.71	4.71	4.28	1.24
Milk (three weeks after calving) .	1.0330	13.52	13.77	4.60	3.34	5.00	0.58

Engling gives the composition of colostrum from a single cow as follows:

Time after Calving	Specific Gravity	Fat	Casein	Albumin	Sugar	Ash	Total Solids
Immediately . .	1.068	3.54	2.65	16.56	3.00	1.18	26.93
After 10 hours .	1.046	4.66	4.28	9.32	1.42	1.55	21.23
After 24 hours .	1.043	4.75	4.50	6.25	2.85	1.02	19.37
After 48 hours .	1.042	4.21	3.25	2.31	3.46	0.96	14.19
After 72 hours .	1.035	4.08	3.33	1.03	4.10	0.82	13.36

The average of twenty-two analyses of colostrum from different cows by Engling showed total solids 28.31, fat 3.37, casein 4.83, albumin 15.85, sugar 2.48, ash 1.78.

ACIDITY OF MILK

The reaction of fresh milk depends on the indicator used in making the test. When litmus is used as the indicator, the reaction is usually amphoteric, that is, red litmus paper is turned blue and blue litmus paper is turned red. If methyl

orange is the indicator, the reaction is alkaline, while with phenolphthalein it is acid. Van Slyke and Bosworth explain the reaction in fresh milk as follows:

"Both fresh milk and the serum from fresh milk show a slight acid reaction to phenolphthalein. This has been believed to be due to casein or acid phosphates in the milk or to both. The fact that fresh milk and its serum are strongly alkaline to methyl orange indicates that the acidity is due to acid phosphates, though it does not necessarily show that acid caseinates are not also responsible for some of the acidity. The results of our work given in the preceding pages furnish aid in determining to what compounds in milk the acid reaction to phenolphthalein is due.

"A 1000 c.c. sample of milk was obtained from each of eight cows immediately after milking and chloroform (50 c.c.) was added to this at once. The acidity of the milk and of the milk-serum was determined after treatment with neutral potassium oxalate according to the method of Van Slyke and Bosworth.[1] The results are given below:

ACIDITY OF MILK AND MILK-SERUM

NUMBER OF SAMPLE	NUMBER OF C.C. OF $\frac{N}{10}$ ALKALI REQUIRED TO NEUTRALIZE 100 C.C. OF —	
	Milk	Milk-serum
1	4.8	5.0
2	6.2	6.2
3	4.2	4.2
4	6.0	5.8
5	6.4	6.4
6	4.4	4.4
7	7.0	6.8
8	6.6	6.4

[1] N. Y. Agr. Expt. Sta. Tech. Bul. No. 37, p. 5.

"These figures show that the acidity of fresh milk is the same as that of its serum, which means that the constituents of the milk causing acidity are soluble constituents contained in the serum. Since the serum contains phosphates in amounts sufficient to furnish two to four times as much acid phosphates as is required to account for the acidity, and since, moreover, no other acid constituents of the milk-serum are present in more than minute quantities and are wholly insufficient to cause the observed degree of acidity, it appears a reasonable conclusion that the acidity of fresh milk is due to soluble acid phosphates. This conclusion is further strengthened by the results given in the preceding pages, which go to show conclusively that the insoluble constituents of fresh milk are neutral in reaction, consisting largely or wholly of neutral calcium caseinate (casein Ca_4), neutral di-calcium phosphate ($CaHPO_4$), and fat.

"Both fresh milk and the serum from fresh milk show a slight acid reaction to phenolphthalein but are strongly alkaline to methyl orange, indicating that acidity is due, in part at least, to acid phosphates. In eight samples of fresh milk, the acidity of the milk and of the milk-serum was determined after treatment with neutral potassium oxalate. The results show that the acidity of the whole milk is the same as that of the serum and that, therefore, the constituents of the serum are responsible for the acidity of milk. There is every reason to believe that the phosphates of the serum cause the observed acidity."

CHAPTER III

FACTORS THAT AFFECT THE COMPOSITION OF MILK

In the preceding chapter it has been seen that cow's milk is subject to wide variations in composition. There are many things which cause these variations, certain conditions affecting the composition of the milk permanently, others causing only transient modifications. Probably all the constituents of milk are subject to more or less fluctuation in percentage and amount, but those which show the greatest changes are the water, the fat, and the total solids.

FACTORS WHICH AFFECT THE WATER-CONTENT OF COW'S MILK (Van Slyke)[1]

Amount of variation.

The amount of water normally contained in milk varies, depending on such conditions as individuality, breed, stage of lactation, age, character of food, amount of water drunk, state of health. In the case of single milkings of individual cows, the water may vary from 82 to 90 per cent or more; in the case of milk from herds of cows the water varies less, usually ranging from 86 to 88 per cent.

The influence of breed.

The following figures from the records of the New York Agricultural Experiment Station illustrate the influence of breed on the water-content of milk:

[1] Modern Methods of Testing Milk and Milk Products, Orange Judd Co.

INFLUENCE OF BREED UPON WATER-CONTENT OF MILK

NAME OF BREED	PERCENTAGE OF WATER IN MILK
Holstein-Friesian	88.20
American Holderness	87.35
Ayrshire	87.25
Shorthorn	85.70
Devon	85.50
Guernsey	85.10
Jersey	84.60

The influence of lactation.

The variation of water in milk, as affected by advance of the lactation period, is illustrated by the following figures, which cover a period of ten months from the time of calving:

MONTH OF LACTATION	PERCENTAGE OF WATER IN MILK
1	86.00
2	86.50
3	86.53
4	86.36
5	86.25
6	86.00
7	85.82
8	85.67
9	85.54
10	85.17

There is noticeable a general tendency for the amount of water in milk to increase for the first three months of lactation, after which there is a continuous decrease to the end of the lactation period.

FACTORS WHICH INFLUENCE PERCENTAGE OF FAT AND SOLIDS IN MILK

There is great variation in the percentage of fat in normal milk. The average of large numbers of analyses, including milk of the different breeds during the entire year, shows that the average percentage of milk-fat in this country is not far from 4 per cent. If individual herds are considered on a yearly basis, the average may vary from approximately 3 per cent to 5 per cent or higher. Between different individual cows, the average may vary even more. Many of the conditions that affect the percentage of fat in milk are fairly well known, while others are little understood. Some of the well-recognized conditions that influence the fat content of milk will be considered.

Influence of breed (Van Slyke).[1]

It is well known that the percentage of fat in milk varies in a somewhat characteristic way with the kind of breed of cow. While there is marked variation in individuals of the same breed, there is found to be a fairly uniform difference, more or less marked, if we consider the averages of several individuals. It is largely owing to this influence that we find the milk of one country differing from that of another, or the milk of one section of a country differing from that of another section. For example, the average amount of fat in milk in Germany and Holland is fully ½ per cent lower than in this country, because the prevailing breeds of cows there are those producing milk comparatively low in fat. The following figures, taken from the records of the New York (Geneva) Agricultural Experiment Station, represent averages of many individuals for several periods of lactation:

[1] Loc. cit.

Name of Breed	Per Cent of Fat in Milk		
	Average	Lowest	Highest
Holstein-Friesian	3.36	2.88	3.85
Ayrshire	3.60	3.20	4.24
American Holderness	3.73	3.49	3.92
Shorthorn	4.44	4.28	4.56
Devon	4.60	4.30	5.23
Guernsey	5.30	4.51	6.13
Jersey	5.60	4.96	6.09

The following, compiled by Wing from a large number of analyses made at various American Agricultural Experiment Stations, will give a general idea of the average composition of the milk of the more common breeds, so far as it relates to total solids and fat:

Influence of Breed on Solids and Fat in Milk

	Solids	Fat
Jersey	14.70	5.35
Guernsey	14.71	5.16
Devon	14.50	4.60
Shorthorn	13.38	4.05
Ayrshire	12.61	3.66
Holstein-Friesian	11.85	3.42

Influence of individuality of cow.

While there is great difference in the average fat-content of milk from the different breeds, there is also wide variation in the individual animals within any given breed. It would be difficult to find two cows in any breed whose milk contained the same percentage of fat; in fact, the variations between individual cows in a breed are likely to be as great as the average

differences between the breeds. This is shown by the data in the following table representing the milk from individual animals in the different breeds.

VARIATION IN PERCENTAGE OF FAT OF MILK OF INDIVIDUAL COWS

BREED	NUMBER OF MILKINGS	FAT-CONTENT		
		Average	Highest	Lowest
		per ct	per ct.	per ct.
Ayrshire	27	3.93	4.36	3.49
Holstein	28	3.07	3.79	2.40
Holstein	28	3.18	3.67	2.71
Jersey	28	5.31	6.31	4.56
Shorthorn	27	4.08	5.29	3.46
Holstein	20	2.98	3.63	2.24
Holstein	19	2.62	4.15	1.67

Influence of age of cow on fat-content of milk (Wing).[1]

A notion is prevalent that the percentage of fat in the milk is also affected by the age of the cow; that during the first and second periods of lactation the young cow usually gives milk poorer in fat than when she is mature. During the years of greater vigor the percentage of fat is supposed to be fairly uniform; but in cows of advanced age it may sometimes again fall to a low point. Recently some records have been published that go to show that the age of the cow has little, if any, influence on the percentage of fat in the milk. In the oue case the observations were made on a large number of cows of all ages, for a week at a time, comparatively early in the period of lactation. In the other the observations were made on a single herd extending over several years, and the percentages of fat

[1] Milk and Its Products.

are the average for the whole period of lactation. The percentages of fat for the different ages are as follows:

	"Official" Weekly Tests of Holstein-Friesian Cows		Observations on Cornell University Herd 1891-8	
	Number of Cows	Average Per Cent Fat	Number of Cows	Average Per Cent Fat
2-year-olds	147	3.29	25	3.71
3-year-olds	81	3.31	25	3.71
4-year-olds	59	3.41	18	3.68
5-year-olds	37	3.42	12	3.60
6-year-olds	36	3.34	8	3.49
7-year-olds	22	3.25	5	3.68
8-year-olds	14	3.40	4	3.89
9-year-olds	10	3.37		
10-year-olds	9	3.83		
11- and 12-year-olds . .	4	3.57		

Influence of stage of lactation on fat-content of milk (Van Slyke). From the time a cow "comes fresh in milk" up to the time she becomes "dry," the composition of the milk undergoes gradual changes, which are quite independent of other factors. The period of lactation varies in length with different individual cows, but, for practical purposes, lasts about ten to twelve months. The changes observed in the percentage of fat during the progress of the lactation period are quite marked and fairly regular, without reference to individual or breed. The colostrum, which is the secretion produced by a cow soon after calving, is very different in composition from normal milk, and is not considered at all in our discussion of the constituents of milk. The figures presented in the following table represent the monthly averages of nearly 100 different lactation periods:

VARIATION OF PERCENTAGE OF FAT IN MILK WITH ADVANCE OF LACTATION

Month of Lactation	Per Cent of Fat in Milk	Percentages in Comparison with First Month
1	4.30	100.0
2	4.11	95.6
3	4.21	97.9
4	4.25	98.8
5	4.38	101.9
6	4.53	105.3
7	4.57	106.3
8	4.59	106.8
9	4.67	108.5
10	4.90	114.0
11	5.07	118.0

In studying this table, we notice that the percentage of fat decreases in the second month, as compared with the first, *and then begins to increase, continuing to increase from month* to month during the entire period of lactation. The rate of increase is more rapid during the last two or three months than previously. Such behavior appears to be the general rule. Variation from the comparative degree of regularity observed in the foregoing table may, of course, appear in the case of individuals.

Van Slyke also shows " the influence of advancing lactation upon the percentage of fat as observed in the case of milk used at cheese-factories. In general, dairymen have their cows begin the period of lactation in March and April, so that milk taken to a cheese-factory represents, during the season, stages of the lactation period extending from about the second to the eighth months. Cows kept under ordinary farm conditions are subject to greater variations of external influences than those used in the investigation represented by the figures in the pre-

ceding table. The figures in this table represent results secured in both New York and Wisconsin."

Variation of Fat in Cheese-factory Milk with Advance of Lactation

Month	Per Cent of Fat in Milk		Percentages in Comparison with First Month	
	New York	Wisconsin	New York	Wisconsin
April	3.43	3.48	100.0	100.0
May	3.58	3.49	104.4	100.3
June	3.64	3.50	106.1	100.6
July	3.62	3.55	105.5	102.0
August	3.84	3.63	112.0	104.3
September	3.98	3.84	116.0	110.3
October	4.23	4.08	123.3	117.2

Variation from day to day in herd milk.

Since the composition of milk from the different breeds and from individual cows varies decidedly, it is reasonable to expect more or less variation in the milk from different herds. Not only is this true, but there is also variation in the fat-content of milk from the same herd from day to day. Daily variations will normally be larger in herds where but few cows are included than they will be in large herds, but in herds of average size there will normally be daily variations in the percentage of fat.

Variations from day to day in individual cow.

Individual cows will sometimes show very marked variations in both the percentage and amount of fat from milking to milking. An extreme example of this variation is given by Fraser in a two-day record of a cow being milked three times daily on official test where the cow appeared to be in perfect health and with no apparent cause for the wide variation.

DAILY VARIATION IN MILK AND FAT FROM INDIVIDUAL COW

Date	Milking	Lb. Milk	Per Cent Butter-fat	Lb. Butter-fat
June 30	P.M.	3.0	2.7	.083
July 1	A.M.	12.0	3.1	.372
July 1	Noon	7.1	3.1	.199
July 1	P.M.	7.6	3.0	.228
July 2	A.M.	13.2	6.7	.884
July 2	Noon	6.9	4.2	.290

Variation of fat-content in different portions of milk drawn from the udder.

It is a well-known fact that different portions of the milk drawn from the udder contain varying percentages of fat. The first milk drawn (the fore-milk) normally is very low in fat. As the milking progresses, the fat-content increases till the last portion (the strippings) is reached, which is much richer in fat. This increase between the first and last milk usually amounts to several per cent. The following figures, reported by Van Slyke,[1] illustrate the general rule that the first milk drawn contains least fat, the milk last drawn being the richest in fat:

	Per Cent of Fat in Milk		
	Cow 1	Cow 2	Cow 3
First portion drawn	0.90	1.60	1.60
Second portion drawn . . .	2.60	3.20	3.25
Third portion drawn	5.35	4.10	5.00
Fourth portion drawn (strippings)	9.80	8.10	8.30

[1] Loc. cit.

The following data by Leach shows the difference in fat and solids between fore-milk and strippings in the case of two cows:

Number of Cow	Per Cent Water	Per Cent Solids	Per Cent Fat
(1) Fore-milk	88.17	11.83	1.32
Strippings	80.82	19.18	9.36
(2) Fore-milk	88.73	11.27	1.07
Strippings	80.37	19.63	10.36

The percentage of albuminoids, sugar, and ash is nearly the same in both fore-milk and strippings.

The gradual increase in fat and total solids is shown by the following data reported by Baussingault:

Portion of Milk	1	2	3	4	5	6
	per ct.	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*
Total solids	10.47	10.75	10.85	11.23	11.63	12.67
Fat	1.70	1.76	2.10	2.54	3.14	4.08
Solids not fat	8.77	8.99	8.75	8.69	8.49	8.59

Composition of milk from different quarters of udder.

It is also known that the percentage of fat in milk varies in different quarters of the udder of a cow, and also varies more or less in each quarter with the order in which the teats are milked.

Beach [1] studied the quality of milk from the different quarters of the udder by drawing the milk in the usual manner except that four three-quart pails were used, the milk of each quarter being milked into a separate pail. Each lot was then weighed and tested. The following table is representative of the results obtained:

[1] Storrs Report, 1904, p. 132.

No. of Cow	Total Milk Yield	Per Cent of Total Milk Yield, Front Udder		Per Cent of Total Milk Yield, Rear Udder		Babcock Test			
						Front Udder		Rear Udder	
		Right Quarter	Left Quarter	Right Quarter	Left Quarter	Right Quarter	Left Quarter	Right Quarter	Left Quarter
	lb.					per ct.	per ct.	per ct.	per ct.
1	11.2	25.0	18.8	25.0	31.2	6.4	7.2	7.4	6.2
2	12.7	21.3	23.6	31.5	23.6	4.2	4.0	4.2	4.4
3	11.0	17.3	17.3	30.9	34.5	4.6	4.2	4.0	4.6
4	10.4	20.2	15.3	29.9	34.6	4.4	4.4	5.6	5.6
7	7.5	17.4	20.0	25.3	37.3	4.4	3.8	3.6	3.2
8	10.2	19.5	24.5	33.3	22.7	5.1	5.2	5.4	5.2
16	10.8	16.7	13.9	32.4	37.0	4.2	4.4	4.6	4.6
17	6.0	18.3	23.3	21.7	36.7	6.3	4.6	5.0	4.8
18	15.8	25.3	22.2	27.2	25.3	4.0	4.4	4.6	4.6
19	12.8	11.0	21.1	31.2	36.7	5.6	4.6	5.3	5.2
20	6.1	19.7	21.3	29.5	29.5	5.4	6.0	6.0	6.0
21	10.3	19.4	24.2	28.2	28.2	3.4	4.2	3.4	3.6
22	10.3	11.7	17.5	38.8	32.0	2.8	3.0	2.6	2.4
23	20.5	19.6	24.4	25.8	30.2	3.1	3.6	3.0	3.5
24	5.9	11.9	20.3	32.2	35.6	4.8	4.8	5.0	4.4
Average	10.7	18.3	20.5	29.5	31.7	4.58	4.56	4.55	4.54

It will be seen that there were great differences in the percentage of fat in the milk of the different quarters when individual cows are considered, but that there were practically no differences when the averages for the fifteen cows are considered.

Variation of time between milkings in relation to the fat-content of milk (Van Slyke).[1]

As a rule, the longer the time between two successive milkings, the smaller is the percentage of fat in the milk; and the shorter the time between milkings, the greater the percentage of fat. When the time between milkings is uniformly equal, the variation of fat in milk is small, provided the general environment of

[1] Loc. cit.

the animal is the same. However, as there are not commonly such entirely uniform conditions of surroundings during the day and night, there appears to be a common tendency for the presence of a little more fat in the morning's milk, even when milkings are apart the same length of time.

Influence of methods of milking and environment on composition of milk.

Babcock [1] carried out a series of trials to determine the effect, on the composition of milk, of such variations as milking one teat at a time, milking fast and slow, change of milkers, change of stable, and the like. He gives the following general conclusions as a result of his work:

"The elaboration of milk does not proceed at a uniform rate from milking to milking, but is most active at the time of milking, and is dependent not only upon the stimulus which the milk glands derive from the manipulation of the teats and udder, but upon the nervous condition of the animal at the time of milking.

"In consequence of this, slight changes in the conditions under which the milking is done may have a decided influence upon both the yield and quality of milk. As a general rule the quality of milk, measured by the percentage of fat which it contains, is more sensitive to changes of this kind than is the yield of milk. Among the changes which appear to have most influence in this respect, the following are of especial importance, viz.: change in the interval between milkings and in the rate of milking; change of milkers and manner of milking, especially if the manipulation of the teats and udder be different; change of environment and any circumstance which excites or even slightly disturbs the animal at the time — excitement between milkings, if the cow has become quiet before milking, appears to have comparatively little influence. As would be expected,

[1] Babcock, Wis. Report, 1889, pp. 61–62.

there is a great difference in cows in this respect, some being very sensitive, while others are scarcely affected at all. In our experiments cows that have been giving milk for a long time have been less sensitive in this respect than fresh cows that were giving a large quantity of milk, but this may have been due to individual characteristics of the animals tested and not to the advanced period of lactation. I would recommend, therefore, in order to obtain the best results from any cow that first of all she be treated kindly, all sources of excitement being avoided so far as possible. She should also be fed and milked at regular intervals, by the same person, and all conditions should be maintained as nearly uniform as possible at all times. It is my opinion that kind treatment and pleasant surroundings will have a greater influence upon the quality of milk than the kind of food, provided that the ration given contains sufficient nutriment for the maintenance of the animal."

Influence of drouth on composition of milk.

In a study of the milk of fifty herds of cows, Van Slyke found that the chemical composition was affected by a drouth during the summer months. The constituent most affected was the casein, which decreased both in actual percentage and also in relation to the fat. The extent of this variation is shown in the following table:

TABLE SHOWING VARIATION OF FAT AND CASEIN AS AFFECTED BY SUMMER DROUTH — Van Slyke[1]

MONTH	POUNDS OF FAT IN 100 POUNDS OF MILK	POUNDS OF CASEIN IN 100 POUNDS OF MILK	POUNDS OF CASEIN FOR ONE POUND OF FAT IN MILK
May	3.58	2.40	0.67
June	3.59	2.33	0.65
July	3.71	2.20	0.59
August	4.04	2.26	0.56
September	3.97	2.47	0.62
October	4.20	2.69	0.64

[1] Geneva, Bul. 105, N. S., p. 132.

Effect of food on percentage of fat in milk.

The question as to whether the percentage of fat can be increased by feeding has long held the attention of dairymen. Much experimental work has been done on this subject, and while the results differ somewhat, in the main, they agree in demonstrating that, while sudden or radical changes in feed may affect the percentage of fat in the milk, it is not possible materially to increase the percentage of fat at all permanently. Following changes in feed, the percentage of fat soon tends to return to the normal for the particular cow or herd.

After studying the effect of food on the quality of milk, Whitcher [1] of the New Hampshire Station states his conclusions as follows:

"I feel warranted in saying that a given animal by heredity is so constituted that she will give a milk of certain average composition; by judicious or injudicious feeding the amount of milk daily may be very largely varied, but the quality of the product will be chiefly determined by the individuality of the cow. A Shorthorn cow can never, by feeding, be changed into a Jersey; and the man who starts out to increase the fat in milk by simply changing the food has, in my opinion, a very difficult task to perform. Slight variations are always cropping out, whether we change the food or not, but changes of per cent of fat, of any considerable amount, do not appear to trace to food influence, so long as the food is reasonably well proportioned and sufficient in quantity.

"Quantity is the result of food influence. Quality is the result of the make-up of the animal."

The influence of feed was studied at the New York Experiment Station by feeding cows rations poor or rich in protein and in fat. The results obtained are reported [2] as follows:

[1] 3d Ann. Rept. New Hampshire, p. 155.

[2] New York State Experiment Station, Bulletin No. 197.

Effect of Variations in Ration upon the Milk

Cow 12. Variations in Protein Supply

Period	Changes in Ration	Milk Yield Daily	Solids in Milk	Fat in Milk
		lb.	*per ct.*	*per ct.*
Jan. 30 to Feb. 6	Maximum protein fed (2.6 lb. daily)	35.1	12.92	3.72
Feb. 6 to 16 . .	Maximum protein fed	32.2	13.04	3.68
Feb. 16 to 26 .	Protein diminishing, carbohydrates increasing	30.1	13.36	3.92
Feb. 26 to Mar. 8	Protein still diminishing, carbohydrates still increasing .	28.4	13.37	3.87
Mar. 8 to 18 . .	Protein at minimum (1.6 lb. daily)	26.0	13.47	4.01
Mar. 18 to 28 .	Protein increasing, carbohydrates diminishing . . .	26.1	13.65	4.05
Mar. 28 to Apr. 7	Protein still increasing, carbohydrates still diminishing .	26.5	13.73	4.11
Apr. 7 to 14 . .	Protein at maximum (2.6 lb. daily)	26.1	13.78	4.08

Cow 10. Variations in Food Fat Supply

		lb.	*per ct.*	*per ct.*
Jan. 30 to Feb. 6	Normal ration (fat fed daily 8 lb.)	22.9	14.31	4.74
Feb. 6 to 13 . .	Ration unchanged	22.8	14.20	4.74
Feb. 13 to 20 .	Ration unchanged	22.8	14.20	4.75
Feb. 20 to 27 .	Ration unchanged	23.5	13.90	4.46
Feb. 27 to Mar. 6	Food fat increasing	23.4	14.09	4.60
Mar. 6 to 13 . .	Food fat at maximum (1.4 lb. daily)	23.7	14.17	4.76
Mar. 13 to 20 .	Food fat diminishing . . .	24.6	13.81	4.44

"Cow 12 fed a fat-poor ration in which the protein supply was gradually decreased from 2.6 lb. daily to 1.6 lb. and then gradually restored to the maximum, with accompanying increase and decrease in carbohydrates so that the digestible dry matter of the ration was kept fairly uniform; Cow 10 fed a

ration with normal supply of fat at first which was gradually increased to 1.4 lb. daily, then gradually restored to the normal; these rations were quite varied in character and contained some fat-extracted foods; yet showed a quite uniform digestibility of about 70 per cent of the dry matter.

"There is nothing in these data to warrant the conclusion that supplying more or less protein or more or less fat to a milch cow causes material changes in the milk. In the case of Cow 12 her milk suffered a gradual and quite constant increase in its proportion of solids and of fat, but this change was in no way disturbed in its progress by the fall or rise in the proportion of protein in the food.

"With Cow *10*, the increase of the food fat to 1.4 lb. daily, a most abnormal quantity, did not raise the milk-fat above what appeared to be the normal proportion. These results stand in accord with the outcome of many other carefully conducted investigations.

"The marked changes in protein-content and in fat-content of rations did not produce noticeable changes in the character or composition of the milk. A lessening of protein supply in the food did not produce a corresponding decrease of protein in the milk solids, but caused a marked lessening of protein decomposition in the body."

The effect of a ration rich in palm-nut meal has been studied by Anderson,[1] who used six cows divided into two lots of three each. Previous to the experiment all of these cows had received the same grain mixture. The palm-nut meal was fed for a period of six weeks, during which time the grain ration for lot No. 1 contained two parts and that of lot No. 2 four parts of palm-nut meal. He summarizes his results as follows:

[1] C. U. Bul. 173.

Influence of palm-nut meal on percentage of fat.

AVERAGE PER CENT OF FAT IN PERIODS OF THREE WEEKS EACH

		Lot No. 1.			Lot No. 2		
		Glista Netherland	Gem Valentine	Mollie	Mabel 2d	Ruby	Sadie
Usual ration (Dec. 9-Jan. 19.)	1st three weeks	3.06	5.28	2.98	3.94	—	3.21
	2d three weeks	3.39	5.09	2.92	3.77	3.67	3.63
Palm-nut meal ration . . . (Jan. 20 Mar. 2)	1st three weeks	3.32	5.80	3.27	4 32	3.26	3.28
	2d three weeks	3.64	5.80	3.45	4.35	3.27	3.58
Usual ration . . (Mar. 3-April 13)	1st three weeks	3.47	5.80	3 31	3.78	3 00	2.02
	2d three weeks	—	5.84	3.30	4.03	3.14	3.48

RATION UNCHANGED	Belva 2d Narrow Ration	Cherry Medium Ration	Clara Wide Ration
December 9–29	3.02	5.37	5.11
December 30–Jan. 19	2.92	5.58	5.30
January 20–Feb. 9	2.94	5.75	5.68
February 10–Mar. 2	3.14	5.52	5.44
March 3–23	3.23	5.55	5.45
March 24–April 13	3.23	5.47	—

"Among the cows that were fed palm-nut meal it is seen that all in lot No. 1 show in general a higher per cent of fat while the meal was fed than before, but this higher average is kept up for six weeks after the meal was discontinued. Mabel 2d of lot No. 2 is the only cow that shows a lower average both before and after feeding the palm-nut meal than during that period, but her total yield of fat was less on the palm-nut ration than on the usual ration. Ruby and Sadie each had a higher average before the meal was fed and nearly as high after as during the period of feeding the meal. Ruby's high average at the beginning is probably due to her being fresh in milk. A comparison of the records of all the cows in the table shows that with one

exception (Gem Valentine) there are no greater variations among the cows which alternated from the usual ration to palm-nut meal than among those which were fed an unchanging ration. Thus, taking everything into consideration we do not feel warranted in saying that the feeding of palm-nut meal increased the per cent of fat in the milk.

"When the food of the cows was changed from the usual ration to one containing from four to seven pounds of palm-nut meal and then to the usual ration again, there were variations in the fat-content of the milk, but no more nor greater than when the food of the cows was unchanged."

Wing,[1] of the Cornell Station, tested out the effect of additional fat in the ration upon the percentage of fat in the milk, by feeding two pounds a day of tallow, in addition to the regular ration. He summarizes his results thus:

"In this quite extended trial there has been no increase in the fat in the milk by feeding tallow to the cows in addition to a liberal grain ration. These results were obtained with ten different cows, of two breeds of various ages, in various periods of lactation, extending over a period of ten weeks, for at least six of which they ate two pounds a head, each day, of tallow."

The Iowa Station [2] carried out an experiment with four cows to test the effect of sugar-meal and corn- and cob-meal on the composition of the milk.

"The cows were fed in pairs. Nos. 21 and 22 had the corn- and cob-meal ration during period 1, the sugar-meal ration during period 2, and corn- and cob-meal again in period 3. Nos. 33 and 65 had the same feeds in different order; namely, sugar-meal first, then corn- and cob-meal, then sugar-meal again in period 3.

"The rations were fed for a week before the beginning of period

[1] C. U. Bul. 92. [2] Iowa Bul. 14, pp. 126–127, 142.

1; and of the ten-day interval between the succeeding periods, the first three or four days were taken for changing rations, leaving six or seven days of the new ration before the beginning of the period.

"Each period lasted twenty-one days. The cows were weighed on three successive days every two weeks during the experiment. Variations in weights were no greater than usually appear in live weights of such animals, and did not surely indicate either gain or loss."

The results which were obtained as to percentage composition of milk were as follows:

"1. Quality of milk, so far as measured by its percentage of fat, was changed by feed to a much greater degree than was quantity. Two-thirds of the increase in average gross yield of butter-fat was due to improved quality of the milk, and only one-third to increased milk flow.

"2. Sugar-meal produced .58 lb. more butter-fat a 100 pounds of milk than did corn- and cob-meal; this difference is 17 per cent of the amount of fat in 100 lb. of milk produced by corn- and cob-meal.

"3. Sugar-meal produced .73 lb., more total solids a 100 pounds of milk than did corn- and cob-meal; this difference is 6 per cent of the solids in 100 lb. of milk produced by corn- and cob-meal.

"4. As compared with corn- and cob-meal, sugar-meal increased the ratio of fat to 'solids not fat' in 100 lb. of milk, from 396 a 1000 of 'solids not fat,' to 457 a 1000 of 'solids not fat' — an increase of over 15 per cent."

Effect of under- and over-feeding.

The influence of under-feeding and liberal feeding was studied by Wing during a period of four years. A herd of twenty-one cows was selected when they had been normally underfed by the owner.

"A record of the production of the herd in milk and fat was

An Attempt to Increase the Fat in Milk

Records of the Ten Purchased Cows[1]

Year		Number of Weeks in Lactation	Total Pounds of Milk	Total Pounds of Fat	Average Per Cent of Fat	Gain or Loss in Per Cent of Fat
Chloe	1900 . . .	34	3052	130	4.26	
	1901 . . .	33	3722	148	3.98	−.28
Clover	1900 . . .	34	2854	123	4.31	
	1901 . . .	47	5716	274	4.80	.49
Dena	1900 . . .	39	3243	156	4.82	
	1901 . . .	55	6588	355	5.39	.57
	1902 . . .	33	4644	236	5.08	−.31
	1903 . . .	41	3602	180	5.00	−.08
Dinah	1900 . . .	45	4001	169	4.22	
	1901 . . .	21	2561	108	4.24	.02
Patty	1900 . . .	38	4030	172	4.27	
	1901 . . .	44	7137	342	4.79	.52
	1902 . . .	50	7756	352	4.54	−.25
	1903 . . .	35	4568	194	4.25	−.29
Polly	1900 . . .	37	3143	177	5.64	
	1901 . . .	46	5526	346	6.26	.62
	1902 . . .	36	4802	283	5.89	−.37
	1903 . . .	40	2945	184	6.25	.36
Rena	1900 . . .	34	4218	155	3.66	
	1901 . . .	48	8416	320	3.82	.16
	1902 . . .	36	6582	243	3.69	−.13
	1903 . . .	33	5230	180	3.44	−.25
Rita	1900 . . .	39	4435	174	3.92	
	1901 . . .	49	7346	319	4.34	.42
	1902 . . .	44	7832	325	4.15	−.19
	1903 . . .	48	5468	213	3.90	−.25
Stella	1900 . . .	29	2476	129	5.22	
	1901 . . .	38	5203	276	5.31	.09
	1902 . . .	34	4207	206	4.90	−.41
	1903 . . .	34	3886	186	4.79	−.11
Tilda	1900 . . .	19	1965	73	3.71	
	1901 . . .	48	8978	337	3.76	.05
	1902 . . .	36	7686	293	3.81	.05
	1903 . . .	44	5744	196	3.41	−.40

[1] C. U. Bul. 222.

then kept for one entire lactation period on the farm of the owner without in any way changing the conditions under which the animals had lived. At the close of this lactation period, ten cows from the herd were purchased and brought to the University, where they were fed liberally for two years, records of production being constantly kept as before. At the end of the two years, seven cows (three had been disposed of) were returned to the farm from which they were purchased and kept under conditions practically identical with those of the first year, and records kept as before. That is, the experiment is divided into three parts: (1) on a private farm, one lactation period; (2) at the University, two lactation periods; (3) on the private farm again, one lactation period.

"From the above table it will be seen that there were considerable variations in the percentage of fat in the various periods. In order to determine the effect upon the percentage of fat of the more liberal feeding while the cows were at the University, the percentage of fat in the milk of each cow for the first and fourth periods (scant ration) has been averaged and compared with the average of the second and third periods (liberal ration). The results are given in the next table. Only the records of the seven cows that remained in the experiment for the entire time are used in this tabulation.

"The following table shows that, on the whole, the milk was one-quarter of one per cent richer in fat during the whole time the cows were on a liberal ration. The percentage of fat was therefore increased about 6 per cent. Further, each cow without exception gave richer milk while on the liberal ration. It would seem therefore that in the case of these seven cows the percentage of fat was 'materially and permanently increased' by the influence of more and better food and that our thesis is answered in the affirmative, so far as it can be answered in an experiment using only a small number of individuals.

PERCENTAGE OF BUTTER-FAT IN THE MILK OF THE SEVEN COWS AT THE UNIVERSITY

NAME OF COW	AVERAGE PER CENT OF FAT IN MILK 1ST AND 4TH PERIODS SCANT RATION	AVERAGE PER CENT OF FAT IN MILK 2D AND 3D PERIODS LIBERAL RATION	GAIN WHILE UNDER LIBERAL FEED	
			Actual	Per Cent
Dena	4.91	5.24	.33	6.7
Patty	4.26	4.67	.41	9.6
Polly	5.95	6.08	.13	2.2
Rena	3.55	3.76	.21	5.9
Rita	3.91	4.25	.34	8.7
Stella	5.01	5.11	.10	2.
Tilda	3.56	3.79	.23	6.5
Average gain			.25	5.9

"There are, moreover, several features of interest in the first table that will repay further study.

"In general it will be seen that the increase in fat was much the most marked in the second period. In the third period there was a marked reduction and in the fourth period most of the cows gave poorer milk than in the first."

From the results of this work Wing draws the following conclusions:

"In a herd of poorly fed cows an abundant ration easily digestible and rather nitrogenous in character and continued through two years, resulted in an average increase of one-fourth of one per cent of fat in the milk (or a percentage increase of about 6 per cent).

"This was accompanied by an increase of about 50 per cent in total amount of milk and fat produced."

Influence of fatness of cow on percentage of fat in milk.

Eckles[1] has studied the condition of the cow as measured by the amount of fat stored in her body at the time of parturition, in

[1] Missouri Bul. 100.

its relation to the percentage of fat in the milk. The results of his work indicate "that when the cow has a considerable amount of fat stored upon the body at the beginning of the milk period the milk will contain a higher fat percentage for a certain period than will be the case if the same animal is thin in flesh at the beginning of the milking period.

"On the following page are the records from a series of animals, all of which were in good condition and some of them excessively fat at calving time. The records in some cases are not quite complete, which is indicated by the absence of some figures. The first six animals represent the Holstein breed and the last two the Ayrshire.

"It will be noticed by studying these that in each case the percentage of fat starts in high and gradually comes down. The records for the remainder of the lactation period are given in the lower part of the table by months. By comparing the percentage of fat in the milk for the first twenty days with these records for the remainder of the lactation period it will be observed that the fat-content during the first twenty days was abnormally high.

"One of the necessary conditions to bring about this abnormal percentage of fat in the beginning of the lactation period seems to be under-feeding. This is illustrated by the table [page 65]. As is well known to all practical herdsmen, it is impossible to feed a cow that is in good flesh and is at the same time an animal with strong dairy characteristics a sufficient amount of feed during the first month after calving to maintain the weight of the animal. There is certain to be some decline in weight; and for this reason where a cow is more moderately fat at the beginning of the lactation period there is almost certain to be some effect on the richness of milk for a time regardless of whether any special attempt is made to bring this about or not.

"The table is the record of an experiment with a Jersey cow. This animal was fed liberally when dry in order that she might be decidedly fat at parturition. Following the birth of the calf

SHOWING THE HIGH FAT-CONTENT DURING THE FIRST TWENTY DAYS

	Cows' Fat							
Time after Calving	No. 207	No. 220	No. 221	No. 217	No. 209	No. 225	No. 300	No. 306
Days								
1	—	—	—	—	—	—	3.9	—
2	5.8	—	—	4.4	—	—	4.5	—
3	5.7	—	—	4.2	—	—	4.1	—
4	5.4	—	5.4	4.0	—	—	4.0	5.4
5	4.8	5.5	—	4.2	—	—	4.2	5.9
6	4.1	5.9	4.6	3.6	—	3.4	4.5	5.4
7	4.3	5.8	4.9	3.7	—	3.8	4.6	5.3
8	4.2	6.0	4.3	3.8	4.8	4.0	4.4	5.5
9	3.9	5.5	4.4	3.7	4.2	4.1	4.4	5.2
10	3.9	7.1	4.2	3.5	4.2	4.0	4.1	5.4
11	3.6	5.5	4.2	3.7	4.1	3.8	4.2	5.3
12	3.3	4.8	3.7	3.6	3.8	4.0	3.7	5.0
13	3.1	4.6	3.6	3.4	4.0	4.0	4.0	4.6
14	2.9	4.5	3.8	3.2	4.0	3.8	4.1	4.5
15	3.2	4.8	3.6	3.7	—	3.6	3.9	4.5
16	3.0	—	4.2	3.3	3.6	3.7	3.6	4.3
17	2.8	—	3.4	3.2	3.6	3.6	3.6	4.1
18	2.5	—	3.4	3.2	3.2	3.7	3.4	4.4
19	2.9	—	3.8	3.4	3.4	3.6	3.7	4.1
20	2.5	—	3.8	—	3.2	3.7	3.6	—
Months								
3	2.6	3.0	4.0	3.0	3.1	3.2	3.6	3.6
4	2.5	3.0	3.4	3.1	2.9	2.7	3.4	3.5
5	2.8	2.8	3.6	3.6	2.8	3.0	3.9	3.7
6	2.4	3.0	3.5	3.5	3.2	2.8	4.0	4.1
7	2.7	2.7	—	3.3	2.9	—	4.3	4.2
8	3.1	2.8	—	3.4	3.0	—	3.8	4.5
9	3.0	3.2	—	3.4	3.6	—	—	4.9
10	3.4	3.4	—	3.6	3.6	—	—	4.9
11	3.3	3.5	—	4.1	3.4	—	—	—
12	3.3	4.0	—	4.1	3.5	—	—	—
Av. for year	2.8	3.3	—	3.4	3.1	—	3.55	3.83

she was put on a ration that was calculated to be sufficient only to maintain her body weight and she was continued under this condition for thirty days. The grain ration fed was a mixture of corn 4 parts, bran 2 parts, and oilmeal 1 part. With this was fed the best quality of alfalfa hay. The amount of each given is shown in the table. At the beginning she produced 21

EFFECT OF UNDER-FEEDING UPON THE PERCENTAGE OF FAT IN MILK

JERSEY COW NO. 20

Days after Calving	Per Cent Fat	Yield of Milk	Grain Fed, Lb.	Alfalfa Hay Fed, Lb.	Weight, Lb.
2	4.37	22.2	3.5	7	830
4	5.80	20.9	3.5	7	807
6	6.89	22.3	3.5	7	790
8	7.21	23.1	3.5	7	787
10	6.60	22.6	3.5	7	785
12	5.86	21.5	3.5	7	780
14	6.82	20.0	3.5	7	765
16	6.00	19.1	3.5	7	755
18	5.07	21.8	3.5	7	755
20	4.94	17.2	3.5	7	730
22	6.37	19.0	3.5	7	730
24	6.82	19.6	3.5	7	725
26	5.70	19.1	3.5	7	720
28	6.26	17.8	3.5	7	720
30	5.60	19.9	3.5	7	710
32	5.53	20.4	5.5	11	690
34	4.74	24.4	7	11	710
36	4.28	25.4	7	14	710
38	4.49	25.0	7	14	720
40	4.45	25.0	7	14	710
42	3.98	27.2	7	14	715
44	4.83	26.7	7	14	740
46	4.27	26.1	8	16	700
48	3.80	25.9	8	16	735
50	4.23	27.0	8	16	747
52	—	25.6	8	16	725
54	4.01	25.7	8	16	715
56	4.47	23.7	8	16	720
58	4.37	24.3	8	16	740

lb. milk a day and during the thirty days the decline was slight. At the end of thirty days she was producing $19\frac{1}{2}$ lb. a day. During this time the live weight decreased 115 lb. The percentage of fat in the milk was taken by extraction after the usual chemical method on each second day. The results are shown in the table. It will be noted that the percentage of fat is unusually high down to the twenty-fourth day. As soon as the feed was raised to near normal amount the percentage of fat immediately dropped from between 5.5 and 6.0 to close to 4.5. It will be noted further that the percentage of fat remained low from the thirty-fourth day to the fifty-eighth. During the remainder of this lactation period this animal was kept on a normal ration and the percentage fat for the third month, that is, the next following the figures given, was 4.0 per cent. The fourth month was 4.10; fifth month 4.5; sixth month 5.2; seventh month 5.2; eighth month 5.6; ninth month 5.5 per cent. The average for the entire year was 4.8 per cent. It will be seen from this that the percentage of fat during this first thirty days' period was entirely abnormal for this animal. Records are available for the same cow for three complete lactation periods in addition, during which she varied from 4.6 to 5.3 as an average."

From the results of his work on this subject Eckles draws the following conclusions:

"The percentage of fat in milk can be influenced to a marked extent for the first twenty to thirty days by the fatness of the animal at parturition. This influence appears to extend in some cases in a less degree for at least three months.

"Under-feeding of the animal after parturition seems to be a necessary condition to bring about this abnormal percentage of fat in the milk."

Effect of period of heat.

For the purpose of acquiring definite information on this subject, Doane analyzed the milk of individual cows in normal

condition and during the period of heat. The summary of his results is given in the following table:

EFFECT OF PERIOD OF HEAT ON COMPOSITION OF COW'S MILK
(Doane)

Cow No.	Condition	Fat	Protein	Casein	Sugar
21	Normal	5.2	3.49	2.69	5.21
	Heat	5.7	3.42	2.57	4.99
27	Normal	5.1	3.14	2.28	4.92
	Heat	5.3	3.13	2.28	4.94
41	Normal	5.7	3.35	2.39	4.81
	Heat	5.4	3.40	2.33	4.83
15	Normal	4.2	3.19	2.27	4.74
	Heat	4.5	3.27	2.28	2.73
Average of all . .	Normal	5.1	3.29	2.41	4.92
	Heat	5.2	3.20	2.37	4.87

Doane concludes: "From these results, and as far as chemical analyses show, it would seem that the milk from cows during the 'period of heat' is in a practically normal condition, and fit for consumption.

"While the chemical analysis shows the milk to be practically normal, yet there is a possibility that it may contain some physical characteristics, or enzymes, which, when consumed by an infant or invalid, would disagree with them."

ACIDITY OF MILK AFFECTED BY SILAGE

The influence of silage on the acidity of milk was studied by Turner [1] and Beach with two cows. The experiment was divided into three periods in which each cow was alternately fed a ration with and without forty pounds of silage a day.

"The milk of both cows was treated exactly alike, and was

[1] Storrs Report, 1904.

titrated simultaneously. The test covered three periods. During Period I both cows were fed a ration containing about forty pounds of silage a day, which they had been receiving for five months or more. In Period II Naomi's Beauty was fed on the silage ration, while Ethel's Fancy received a ration without silage. During Period III the ration was changed for both, Ethel's Fancy going back to the silage, while Naomi's Beauty received none. The results are given below.

Result of Acidity Test

Period	Length of Feeding Period	Number of Samples	Naomi's Beauty		Ethel's Fancy	
			Silage	No Silage	Silage	No Silage
			per ct.		*per ct.*	*per ct.*
I	Up to May 13th	3	0.11	—	0.16	—
II	May 13th to 20th	4	0.11	—	—	0.19
III	May 20th to 27th	9	—	0.13	0.19	—

"As may be seen from these figures, there was apparently a slight increase in acidity when the cows were 'taken off' a silage ration, but the difference is so small that it may probably be attributed to chance variations. There is a much more noticeable difference between individual cows, as is shown by the following analyses, all on silage rations: 'Brownie,' average of six analyses, 0.19 per cent; 'Molly 2d,' average of six analyses, 0.185 per cent; 'Naomi's Beauty,' average of seven analyses, 0.11 per cent; and 'Ethel's Fancy,' average of twelve analyses, 0.175 per cent. . The mixed milk of the herd of twenty-five cows on grass (May 25th to 27th) showed as an average of six analyses 0.175 per cent of acidity."

CHAPTER IV

PHYSICAL PROPERTIES OF MILK

IF whole milk is examined under a microscope, the fat appears in the form of globules with a pearly white luster floating in the opaque serum (Fig. 2). If leucocytes are present, as they

FIG. 2. — The appearance of cream, milk, and skimmed-milk when examined through a high-power microscope. The round bodies are fat globules that float in the serum, or watery part of the milk.

usually are, they appear as relatively large cells with one or more nuclei.

FORM OF THE FAT GLOBULES

The fat exists in the milk not in solution but in the form of an emulsion, the individual globules being held in their spherical form by reason of the surface tension of the liquid fat. The viscous nature of the milk-serum also aids in maintaining the normal form of the globules. It was formerly believed that each

fat globule was surrounded by a membrane, but this theory has been almost abandoned at the present time.

SIZE AND NUMBER OF FAT GLOBULES

The size and number of fat globules in milk may vary widely in different samples. The factors which seem to influence the size and number of the globules are the breed, the age, and the stage in the period of lactation.

Influence of breed.

Woll [1] made extended studies on the size and number of fat globules in the milk of cows entered in the breed tests at the World's Columbian Exposition. He summarizes the results obtained from the Jersey, Guernsey, and Shorthorn breeds in the following table:

NUMBER AND SIZE OF FAT GLOBULES FROM DIFFERENT BREEDS

Breed	Number of Cows	Average Number of Days from Calving	Number of Globules in .0001 Cmm.	Relative Size	Average Diameter of Globules
					mm.
Jersey	25	156	166	290	.00395
Guernsey	25	151	190	217	.00358
Shorthorn	24	150	194	177	.00335
Average		152	183	228	.00363

It will be noted from these figures that the number of fat globules was greatest in the milk of the Shorthorns and smallest in the Jerseys. At the same time, the average size of the globules was decidedly greater in the milk of the Jerseys and smallest in the Shorthorns.

Eckles [2] reports the relative size of the fat globules in the milk of eleven cows representing four breeds as follows:

[1] Wisconsin Report, 1894.

[2] B. A. I., 156, pp. 20–21.

RELATIVE SIZE OF FAT GLOBULES IN MILK OF DIFFERENT BREEDS

JERSEYS	No. 4	No. 99	No. 118	AVERAGE FOR JERSEYS
	309	336	338	328
AYRSHIRES		No. 300	No. 301	AVERAGE FOR AYRSHIRES
		141	160	150
HOLSTEINS	No. 205	No. 206	No. 209	AVERAGE FOR HOLSTEINS
	127	164	134	142
SHORTHORNS	No. 400	No. 402	No. 403	AVERAGE FOR SHORTHORNS
	311	353	211	282

This table shows the same results as noted by others, the Jersey having by far the largest fat globules, while the Holstein has the smallest, the Shorthorn standing between the Holstein and the Jersey. The chief difference between the size of the fat globules with the different breeds is that with the Jersey there is a greater proportion of the larger globules and that the milk of the other breeds contains a limited number as large as the largest in the Jersey milk. The milk of the Holstein breed is especially noticeable in containing a large number of small fat globules, together with a wide variation in size.

The comparative size of the fat globules in the milk of these four breeds is illustrated graphically in Fig. 3, where the average size of the fat globules is represented by the size of the circles in the upper group.

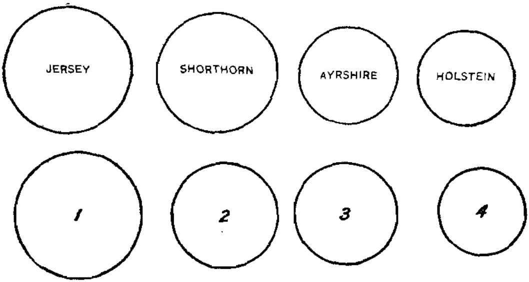


FIG. 3. — Relative size of fat globules in milk. Upper, as influenced by breed. Lower, as influenced by stage of lactation. (1) First 4-week period; (2) fifth 4-week period; (3) ninth 4-week period; (4) thirteenth 4-week period.

Influence of age of cows on number and size of fat globules.

Woll[1] studied the milk of twelve cows to determine the effect of age on the number and size of the fat globules. His work covered a period of three years, samples being taken at the beginning and end of the lactation period. The following table gives the data thus obtained:

EFFECT OF AGE OF COWS ON FAT GLOBULES IN MILK

Year	No. of Glob.	Rel. Size	Milk, Lb.	Fat Per Cent	Day in Milk
AT BEGINNING OF LACTATION PERIOD — THREE-YEAR SERIES					
First	164	293	22.85	4.38	31
Second	155	302	24.17	4.29	15
Third	137	357	24.88	4.29	14
AT END OF LACTATION PERIOD — THREE-YEAR SERIES					
First	311	179	6.77	4.96	300
Second	369	119	12.14	4.52	251
Third	334	147	6.92	4.57	316

[1] Wis. Report, 1894, pp. 237–238.

Woll concludes: "The study of the preceding table will fail o disclose any striking difference as to the influence of advancng age on the fat globules in milk; the tendency seems to be owards fewer globules and a somewhat larger size with increasng age at the beginning of the period of lactation, and, at its nd, the opposite seems to hold true; the differences found are, however, not very marked."

nfluence of period of lactation on size of fat globules.

Woll studied the effect of advancing lactation in "eighty-eight eries of determinations of the milk from nineteen different ows"; he found "that the average number of globnles to .0001 mm. for all cows is, at the beginning of the lactation period, 38, and at its end 367; the average relative size of the globles is 348, and 149 for the beginning and the end of the lactaion period, respectively; the latter figures correspond to a liameter of the average-sized globules of .00419 and .00316 nillimeter, respectively."

Eckles [1] reports data from eleven cows, showing the effect of the advance of lactation on the relative size of the fat globules. His results are given on the basis of four-week periods, and are shown graphically in Fig. 3, where the circles represent the comparative diameter of the average fat globules as found for the eleven cows during the first, fifth, ninth, and thirteenth four-week periods.

SPECIFIC GRAVITY OF MILK

The term "specific gravity" means the weight of a given volume of milk compared with the weight of an equal volume of water at the same temperature. Milk-fat is lighter than water, while the other milk solids, and especially the mineral elements, are heavier. Normal milk is somewhat heavier than water, ts average specific gravity being about 1.032. This means

[1] B. A. I. Bul. 156.

that if a vessel will hold just 100 lb. of water at the temperature of 60° F., it will hold 103.2 lb. of milk of average composition. The weight of the milk divided by that of the water gives 1.032 as the specific gravity of the milk. Since there is considerable variation in the solids in milk, it follows that the specific gravity will also vary; the limits of variation for normal milks usually being between 1.029 and 1.035 at 60° F. Skim milk has a specific gravity of about 1.036–1.038 and milk-fat about 0.900. An increase in fat relative to the other solids, therefore, lowers the specific gravity of milk, while its removal raises the specific gravity. The same is true of the water-content in relation to the solids. Since the volume of liquids is affected by temperature, this fact must be taken into account in determining the specific gravity of milk. As the temperature is raised, the volume of the milk is increased and the specific gravity lowered, while the opposite is true when the temperature is lowered. It is, therefore, necessary to use a standard temperature when determining the specific gravity of milk. The temperature of 60° F. is generally used for this purpose.

ODOR OF MILK

As milk is drawn from the udder, it has a characteristic sweetish, pleasant odor. This is probably largely due to the gases which it contains. Normally the odor of fresh milk is not very pronounced and decreases rapidly when exposed to pure air or cooled. The odor varies with the milk of individual cows, perhaps being influenced by the physical condition of the animal. Milk absorbs foreign odors very quickly. These may come from the feeds eaten by the cows before milking or from odors in the atmosphere to which it is exposed after it is drawn from the cow. These odors become less pronounced as the milk increases in age.

THE YELLOW COLOR OF MILK AND MILK-FAT

The natural yellow color of milk and its products, especially butter, is of considerable commercial value because the public regards this character as an indication of quality. The substance which imparts the yellow color has been given the name of "lactochrome" by some writers, but little has been known of its real nature. Because of the fact that milk and butter are the most highly colored during the early part of the summer when cows are feeding on green grass, it has been assumed that there is some relation between the yellow color of milk and the chlorophyll of green plants. Recently, Palmer and Eckles have studied the yellow color of milk-fat and Palmer and Cooledge the yellow color of whey.

Palmer and Eckles[1] found that the natural yellow pigment of milk-fat is due to the presence of two classes of yellow pigments which are common in green plants known as carotin[2] and xanthophylls. They say:

"Basing the study upon a number of well-defined, characteristic physical and chemical properties of carotin and xanthophylls, it has been shown that the principal pigment of milk-fat is a member of the fast widening group of hydrocarbon pigments, the carotin of green plants. In addition it has been shown that the milk-fat carotin nearly always has associated with it one or more minor constituents whose general properties and characteristics are identical with the xanthophyll group of pigments. Two and possibly three xanthophyll constituents were found in one sample of high-colored butter-fat.

"In addition to the establishment of a chemical relation between carotin and xanthophylls and the yellow lipochrome of milk-fat, it has been possible to demonstrate a much more significant fact, namely that this lipochrome whose origin has

[1] Missouri Research Bul. 10.
[2] So named from the yellow color of carrots.

hitherto been considered to be in the animal body is in reality merely the carotin and xanthophylls of the food, which are absorbed by the body and subsequently secreted in the milk-fat. Numerous feeding experiments show that when the food is deficient in carotin and xanthophylls for a period of time, the milk-fat slowly decreases in color and eventually approaches a colorless condition. The experiments also show that when foods rich in carotin and xanthophylls are given to a cow whose milk-fat is deficient in lipochrome, the color of the milk-fat at once increases in proportion to the amount of pigments fed. This is true, regardless of whether the carotins and xanthophylls are associated with chlorophyll as in green feeds, or whether chlorophyll is completely absent and xanthophylls almost so, as in carrots.

"The pure filtered fat was analyzed colorimetrically by means of the Lovibond tintometer and its standard color glasses. The color of the fat was always compared in one-inch layer. The Lovibond tintometer is shown in Fig. 4.

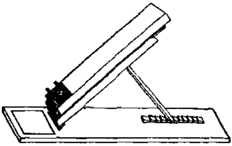


FIG. 4. — Lovibond tintometer used for determining the color of milk-fat.

"The solution (in the present case melted butter-fat) whose color is to be measured is placed in a cell with glass ends (one inch apart in all this work), and the color matched by standard color glasses of various units of yellow, red, or blue, and the color of the solution read by adding together the various glasses of color used to match the unknown color. Melted butter-fat having an orange tint requires only yellow and red to match its color. All readings are made with the instrument pointing towards the daylight (not sunlight). The instrument is quite sensitive towards the yellow glasses below 25 units of yellow, but the sensitiveness decreases considerably above 40 units

of yellow. In other words, it is possible to match the exact color of an "unknown" much more closely when its color is below 30 to 35 units of yellow than when its color is above this value. In a great many cases, and this nearly always applies to butter-fat, it is possible to match the tint of the fat, but the color of the fat is more brilliant than that of the combined standard glasses. In this case an exact match can be obtained by 'damping down' the butter-fat color by inserting in front of it equal units of the three colors, yellow, red, and blue, and recording this as 'light.'

"Before reporting the data dealing with the variation in the color of the butter-fat it may be possible to convey some idea of what the various colors mean when applied to butter-fat by stating that rendered 'June' butter in the one-inch cell will give a color of from 80 to 60 nnits of yellow. Color readings between 45 and 25 units of yellow would accordingly indicate a fairly well-colored to light-colored butter, between 20 and 8 units of yellow would be called light to very light-colored butter, while below these limits, ranging down to 1 or 2 units of yellow, would be called white to 'dead' white, especially if the fat was still in the form of butter."

Source of the yellow color in milk-fat (Palmer and Eckles).

A pure-bred Jersey was changed from a ration rich in carotin and xanthophylls to a ration containing a very small amount of these pigments. The ration rich in carotin and xanthophylls consisted of alfalfa hay and yellow corn. The ration poor in these pigments was composed of bleached clover hay and white corn.

The change from a ration rich in carotin and xanthophylls to one poor in these pigments caused the color of the butter-fat to drop from 43 units of yellow to 8.5 units of yellow, from a well-colored to a very light-colored fat. This change of color was very gradual and required twenty-nine days. It should be stated, however, that the cow did not relish her non-pigmented

ration. She lost weight regularly, and her milk production fell off a great deal. It was apparent that the animal was drawing heavily during this entire period from a storage of pigment in her body.

It may be stated that a slow lowering of the color of the milk-fat, such as took place in this experiment, would be normal for all Jersey cows whose ration is changed to an unpalatable, non-pigmented one like that used in this experiment. The explanation for this is found in the high color of the body fat of this breed of cows. We therefore have here a clear explanation of why Jersey cows will sometimes apparently give yellow milk-fat during the winter months when their food is almost or entirely lacking in carotin and xanthophylls. Under these conditions if the body fat is called upon to supplement the digestion products of the food in the production of milk-fat at the same time the blood-serum storage of pigments is being drawn upon, it is clear that the reduction in color of the milk-fat will be very gradual, and a complete elimination of color may require a long period of time.

The foregoing experiments have shown conclusively that dairy cows, exclusive of breed, are dependent on the carotin and xanthophylls in their feed for the pigment of their milk-fat, in other words, that they cannot produce the pigment which is thus secreted.

Relation between color of milk-fat and breed of cow (Palmer and Eckles).

The question is at once raised as to wherein lies the so-called breed characteristic which is so much emphasized by the breeders of Guernsey and Jersey cattle? It will not be denied that a breed characteristic does exist in connection with the color of butter-fat. We believe, however, that the data now to be presented will show that this breed characteristic has been over-emphasized.

Since the butter-fat is dependent upon the food of the cow for

its color, it was necessary to compare the color of the butter-fat of the different breeds under comparative feeding conditions, in order to obtain a correct estimate of the breed relation.

It would naturally be expected that the most favorable condition for studying the accuracy of the views held by the cattle-breeders and others that some breeds of cows, such as the Jersey and Guernsey, are color producers, while other breeds, such as the Holstein, are not color producers, would be a comparison of the color of the combined fat of several cows of each breed. The table which follows gives such a comparison taken from animals in one herd. The milk and fat production of the various cows varied widely. The comparison was made during the winter months, the only source of pigment being a more or less variable quantity of green alfalfa hay in the ration, which was, however, the same for all the animals.

Relation of Breed to Color of Milk-fat

Breed	Color of Butter-fat		
	Yellow	Red	Light
Jersey	50.0	2.1	0.2
Ayrshire	38.0	1.7	0.2
Shorthorn	34.0	1.6	0.2
Holstein	31.0	1.7	0.2

The most striking fact brought out by this table is that the question of the color of the fat produced by the four breeds represented is not one of presence or absence of color, but rather a question of relative color. The fat from the Jersey cows was unquestionably the highest colored of the four samples, but the fat from the Holsteins also had a very good color, although the butter would probably have been scored as "slightly low in color."

This point of relative color production is also clearly shown when comparing the fat produced by individual members of the breeds. The next table shows the color of the fat from two Jerseys and one Holstein cow under feeding conditions most favorable for the maximum color. These animals were producing about the same amount of butter-fat, and the roughage of their ration consisted for the most part of freshly-cut soybeans, very rich in carotin and xanthophylls.

RELATIVE COLOR PRODUCTION BY DIFFERENT INDIVIDUALS

Cow No.	Breed	Feed	Color		
			Yellow	Red	Light
59	Jersey	Fresh green soybeans and grain . .	54.0	2.5	1.0
34	Jersey	Fresh green soybeans and grain . .	60.0	2.5	1.0
208	Holstein	Fresh green soybeans and grain . .	29.0	1.8	0.5

When comparing the color of the fat produced by individual members of the Jersey and Holstein breeds under feeding conditions favorable for only a moderate amount of color in the fat, the relative color production of the breeds very nearly approaches unity. This is especially true when the fat production and the actual proportion of the ration furnishing the pigments are taken into account. Such a comparison is shown in the following table:

Relative Color Production under Special Feeding Conditions

Cow No.	Breed	Pounds Green Alfalfa Hay	Green Feed (Dry Matter Basis) [1]	Pounds Milk-fat per Day	Color	
					Yellow	Red
34	Jersey	10.0	42%	1.34	29.0	1.6
41	Jersey	12.0	41%	1.78	29.0	1.6
11	Jersey	8.0	40%	1.51	24.0	1.3
13	Jersey	8.0	45.5%	0.58	33.0	1.6
208	Holstein	15.0	35%	1.23	19.0	1.6
211	Holstein	12.0	28%	2.13	17.0	1.5
219	Holstein	12.0	28%	1.50	19.0	1.7

The most interesting feature of the above table is to note that on the basis of the percentage of green dry matter in the ration, the Jersey cows produced the highest-colored fat because they received the highest percentage of green dry matter. By taking into consideration also the difference in fat production, an interesting calculation can be made with the figures of average color, fat production, and percentage of green dry matter in the ration, which will cause the relative color production of the two breeds to approach almost unity.

	Jerseys	Holsteins
Average per cent of green feed in ration	42.1%	30%
Average fat production	1.30 lb.	1.6 lb.
Average color of fat (units of yellow)	29.0	18.0

If it be assumed for the moment that there is no breed characteristic, we can say that 30 per cent green feed in the ration of the Holsteins produces 18 units of yellow in the fat for the same reason that 42 per cent green feed in the ration of the Jerseys

[1] Per cent of moisture free green feed in total ration.

produces 29 units of yellow in their fat. If this is true, then the following proportion would be a true one, *i.e.*:

$$42 : 29 :: 30 : 18$$

The product of the means is not quite equal to the product of the extremes, but gives the result,

$$870 = 756$$

If the amount of fat produced is taken into consideration and each side of this equation is multiplied by the corresponding amount of fat, we have the result,

$$870 \times 1.3 = 756 \times 1.6$$
$$\text{or } 1131 = 1210$$
$$\text{or } 1 = 1.07,$$ which is very near unity.

The relation between the breed of the cow and the color of the fat under two different conditions of feeding is well illustrated by the tables. The color of the fat produced by cows No. 34 and 208 is given under both heavy and moderate pigment feeding. The data in the second table were obtained a number of weeks after those in the first table. The figures show that the change from heavy to moderate pigment feeding caused the color of the milk-fat of the Jersey cow to drop 50 per cent, while a similar change in the feed of the Holstein cow caused a color drop of only 35 per cent.

The pigments of the fat from colostrum milk (Palmer and Eckles).

It is a well-known fact that the first milk drawn after parturition always has a high yellow color. It is not generally known, however, that this high color is usually due entirely to the suspended fat globules. We have many times observed, not only in connection with this study, but also in connection with numerous studies dealing with the chemical composition of milk, that when the fat is entirely removed from colostrum milk the skim milk has the appearance of ordinary skim milk, and the

butter and the rendered fat have a depth of color which is never equaled at any subsequent stage of the lactation period. This characteristic of colostrum milk is common to all breeds of cows, and the high color of the fat continues in cows of all breeds for a short time after parturition and then gradually falls off. The next table gives the color of the milk-fat of several cows shortly after parturition and again a week or two later. The color readings are the Lovibond tintometer readings of a one-inch layer of melted, rendered fat.

COLOR OF THE FAT OF COLOSTRUM MILK

Cow No.	Breed	Roughage Fed	Days after Parturition	Color		
				Yellow	Red	Light
301	Ayrshire	Alfalfa [1]	4	78.0	3.5	1.0
301	Ayrshire	Alfalfa	26	71.0	1.5	0.5
300	Ayrshire	Alfalfa	4	71.0	3.5	1.0
300	Ayrshire	Alfalfa	20	68.0	2.8	1.0
2	Jersey	Alfalfa	13	68.0	2.6	0.5
2	Jersey	Alfalfa	22	57.0	2.5	0.5
2	Jersey	Alfalfa	2	54.0	4.3	1.0
2 [2]	Jersey	Alfalfa	20	50.0	2.5	1.0
20	Jersey	Alfalfa	2	47.0	4.8	1.0
20	Jersey	Alfalfa	25	47.0	2.0	0.5
206	Holstein	Alfalfa	1	50.0	4.7	0.3
206	Holstein	Alfalfa	5	54.0	2.0	0.2

In summing up the results of their work the authors draw the following conclusions:

1. The fat of cow's milk owes its natural yellow color to the pigments carotin and xanthophylls, principally carotin, the well-known, wide-spread, yellow vegetable pigments found accompanying chlorophyll in all green plants.

[1] The alfalfa hay was rich in carotin and xanthophylls.
[2] Second sample taken after next parturition.

2. The carotin and xanthophylls of milk-fat are not synthesized in the cow's body, but are merely taken up from the food and subsequently secreted in the milk-fat.

3. When food practically free from carotin and xanthophylls, such as the cow usually receives during the winter months, is given to a milk-giving cow, the immediate supply of these pigments in the organism is greatly depleted and may be entirely used up, on account of the constant drain upon the supply by the milk glands. The butter-fat accordingly approaches a colorless condition in proportion to the supply of carotin and xanthophylls in the system, the length of time these pigments are kept out of the food, and also, very probably, in proportion to the amount of milk-fat being produced.

4. If food rich in carotin and xanthophylls is given to a milk-giving cow whose milk-fat has become practically colorless by reason of the above conditions, the organism will at once recover its lost pigments and the milk-fat will increase in color in proportion to the amount of carotin and xanthophylls, especially carotin, in the food. Fresh green grass, probably being the richest in carotin of all natural dairy cattle feeds, accordingly produces the highest-colored butter.

5. There is some difference among different breeds of dairy cows in respect to the maximum color of the milk-fat under equally favorable conditions for the production of a high color. Each breed of cows, however, will undergo the same variation in color of the milk-fat which follows a withdrawal or addition of carotin and xanthophylls, especially carotin, to the food. Under some conditions, also, the apparent breed characteristic largely disappears. The popular opinion in regard to the breed characteristic has been overemphasized, and statements in regard to it should in the future be qualified with a statement of the conditions of feed and the like.

6. Under normal conditions cows of all breeds produce very high-colored milk-fat for a short time after parturition. The

pigments of the fat at this time are identical with the normal pigments of the fat. Their increase at this time is probably due to the physiological conditions surrounding the secretion of the milk of the freshening animal.

THE YELLOW PIGMENT OF MILK WHEY

In a similar way Palmer and Cooledge studied the yellow color of milk whey. Since the chief color of milk is due to the carotin in the fat, the pigment in the whey may be considered as the secondary or minor pigment of milk. It is this pigment which gives to whey its greenish-yellow color. They regard this minor pigment to be "lactochrome" which was formerly believed to be chiefly responsible for the yellow color of milk and butter-fat. Studies of the chemical properties of lactochrome showed "its very close relationship to urochrome, the specific pigment of normal urine, the general characteristics of the two pigments being identical." (Pages 85–91 from Palmer and Cooledge.)

Factors influencing the color of milk whey.

During the course of the investigations of the milk whey pigment a wide variation in the color of the whey from the milk of different animals was noticed. This was especially evident when the color of the whey from sheep's milk was compared with the color of the whey from cow's milk, and was also often evident when merely observing two samples of freshly prepared whey from the milk of two different cows. In order to establish a better standard of comparison and study the factors that might be influencing the amount of lactochrome in the milk the following procedure was adopted:

Freshly drawn milk was run through a cream separator at a uniform speed and the casein precipitated from the skim milk with the smallest amount of 10 per cent acetic acid necessary to cause a clear coagulation. A portion of the cloudy yellow filtrate was then boiled for a few minutes to bring down the coagu-

lable proteins. After filtering, the yellow serum which resulted was in some instances cloudy. To get a clear solution in these cases the filtrate was neutralized with ammonium hydroxide, warmed, and filtered. The filtrate was then always perfectly clear. The yellow serum obtained by either of these methods was then placed in a 10 cm. cell and its color compared with the standard color glasses of the Lovibond tintometer. The colors were readily matched. In some cases a few tenths of red were required.

Using the above procedure, color readings of the whey from the milk from forty-three cows and six sheep were made. The color of the sheep's milk whey is given to show how very much higher colored it is in many cases than the whey from cow's milk. The figures for sheep's milk are given in the following table:

Color of Whey from Sheep's Milk

Sample No.	Color, 10 Cm. Layer	
	Yellow	Red
1	7.0	0.9
2	7.0	0.5
3	15.5	0.5
4	24.0	1.2
5	3.5	0.2
6	4.5	0.5

The samples of cow's milk represent four breeds and include four Ayrshires, four Shorthorns, fifteen Holsteins, and twenty Jerseys, all pure-bred dairy animals. The milk production varied from 4.2 to 47.4 lb. a day. The stage of the lactation period of the animals varied from one to thirteen months, and their ages from three to fifteen years. The results of the colorimetric studies have been arranged according to breed, stage of

lactation, age of the animal, and volume of milk production, the results being given in tables.

Influence of breed on the color of milk whey (Palmer and Eckles). The results according to breed are given in the table below. The average tintometer reading for the Ayrshires was found to be 4.75 units of yellow; for the Jerseys, 3.59 units of yellow; for the Holsteins, 2.41 units of yellow; and for the Shorthorns, 2.15 units of yellow.

INFLUENCE OF BREED ON COLOR OF MILK WHEY

BREED	NUMBER OF COWS	AVERAGE UNITS OF YELLOW
Ayrshire	4	4.75
Jersey	20	3.59
Shorthorn	4	2.15
Holstein	15	2.41

These colorimetric averages emphasize what was found by mere observation of even the cloudy yellow whey after removal of the casein, namely, that the Ayrshire and Jersey milk is characterized by yielding much higher-colored whey than Holstein and Shorthorn milk. In some cases it was possible to select the samples of Ayrshire milk from a mixed lot of Ayrshire, Jersey, and Holstein milk, on account of its relatively higher-colored whey. Only in a few cases was the Jersey whey as high colored as the Ayrshire whey.

These figures, showing such a marked difference between the average color of the whey of the milk from the four different breeds, when taken into consideration with the fact that each breed represents widely different conditions of milk production, stage of lactation, etc., would indicate that the color of the milk whey is primarily a breed characteristic. Within narrower limits it also appears to be an individual characteristic.

Influence of the stage of lactation on the color of the whey.

When the results are arranged according to the stage of lactation of the cows, the differences here are not very pronounced, and are hardly definite enough to warrant any conclusions. A calculation, however, shows that 78.5 per cent of the cows which had been in milk for less than five months gave a color reading slightly below the average of the breed.

Influence of the age of the animal on the color of the milk whey.

An examination of the data indicates that the age of the animal may slightly influence the color of the whey. Nearly all the cows over seven years of age, especially the Jerseys, gave color readings above the average for their breed. Of the cows under seven years of age, 70 per cent are below the average. This would indicate that the older the cow, the higher the color of the milk whey. Three of the old cows, however, were also well advanced in lactation, which may cause the apparent influence of the age to lose some of its significance.

Influence of the volume of milk production on the color of the milk whey.

If the average milk production and average color reading of the Holstein cows are compared with the average milk production and average whey color of the Jersey cows, the highest color evidently accompanies the lowest milk production. This does not hold good, however, when comparing either the Jerseys or the Holsteins with the Ayrshires. Similarly the relation of high color to low milk production does not hold good when comparing the Jerseys or Holsteins among themselves.

It must be concluded, then, that the differences in color of the whey among different cows, while perhaps influenced in some cases by the volume of the milk, is not primarily a dilution effect. If any interpretation at all can be put upon the figures given in the tables, it seems that the variation in the color is primarily a breed characteristic, as stated before, with the milk yield, age

of the animal, and possibly the period of lactation as minor influencing factors.

Influence of feed on the color of milk whey.

In addition to the foregoing studies it was considered advisable to study the influence of the food of the cow upon the color of the whey. This would seem to be especially important in view of the fact that in a contemporaneous [1] investigation the food was found to be the important factor in the pigmentation of the milk-fat.

The color of the milk whey was observed with two different cows in two different succeeding periods in which the food had been varied primarily for the purpose of studying the effect upon the color of the milk-fat. The results are given in the following:

INFLUENCE OF FEED UPON THE COLOR OF MILK WHEY

Cow No.	Period	Feed	Color of Fat	Color of Whey
			1 inch layer Yellow	10 cm. layer Yellow
57	1	Bleached clover hay and white corn	8.0	3.5
57	2	Green alfalfa hay and yellow corn	45.0	4.5
			Yellow	Yellow
301	1	Green alfalfa hay, corn silage and grain . .	32.0	5.5
301	2	Bleached timothy hay and white corn . . .	1.3	3.0

The results of these two cases might seem to indicate that some feeds influence the color of the whey as well as the color

[1] Missouri Agricultural Experiment Station Research, Bulletin No. 10 (1914); Jour. Biol. Chem. 17, p. 191 (1914).

of the milk-fat. This is emphasized in the case of Cow No. 301, because the milk production in the two periods is known to have been the same. If there is an influence upon the color of the whey, it certainly is not nearly so pronounced as it is upon the color of the milk-fat. Besides, this apparent result is of no value whatever in explaining the wide difference between the color of the whey of the different breeds, for when those readings were taken all the cows were on the same ration, consisting of alfalfa hay, corn silage, and a grain mixture of corn, bran, and oil meal.

It is to be concluded, then, that the feed has little or no influence upon the color of the milk whey. Certainly slight individual variations in the color of the whey are to be expected from time to time, and it was probably merely accidental that the color of the whey was somewhat lower in each case in the period when the milk-fat was very low-colored, for there was a considerable lapse of time in both cases between periods 1 and 2. This question was not considered of sufficient importance to pursue further.

These investigators sum up the results of their work as follows:

Lactochrome, the yellow pigment of milk whey, is very closely related in chemical and physical properties to urochrome, the specific yellow pigment of normal urine, and is very probably identical with it.

The presence of lactochrome was found to be characteristic of the milk of all breeds of cows tested, *i.e.* Ayrshire, Jersey, Holstein, and Shorthorn. The amount of lactochrome appears to be largely a breed characteristic, with the Ayrshire and Jersey breeds ranking considerably above the Holstein and Shorthorn.

The presence of comparatively large amounts of lactochrome in the milk of some animals is of considerable importance in imparting to milk its characteristic yellow color.

Lactochrome was found in sheep's milk, often in much larger

quantities than in cow's milk, and was also found in traces in human milk.

VISCOSITY OR CONSISTENCY OF MILK (Babcock and Russell)[1]

The consistency of milk or cream is made up of two factors, one dependent on the inherent characteristics of the solution (the milk-serum) and the other belonging to the matter suspended in this solution (fat, casein, and so on).

The effect of the first factor we term viscosity in order to discriminate between substances in solution and in suspension. The combined effect of these two factors is what makes the body or consistency of milk or cream.

The consistency of the milk-serum is due to the viscosity imparted by substances such as the sugar and the ash constituents which are in a state of perfect solution and also by the physical state of the casein and insoluble phosphates which are doubtless suspended in a semi-colloidal condition. These substances differ in their ability to impart consistency to milk-serum, the nitrogenous matter having about three times the influence of the milk-sugar in normal milk.

The influence of the fat on the consistency is purely mechanical, it being wholly in suspension. In part, this is undoubtedly due to the inherent characteristics of the fat globule itself, such as size and its relation to surface tension, and so on, but to a much larger extent to the aggregation of the fat globules into small groups or clots, a condition which is always found to a greater or less extent in normal milk. The effect of these factors is greatly modified in a variety of ways. For example, centrifugal force in separating cream diminishes its consistency to a marked degree; on the other hand, the development of acid in spontaneous souring materially increases the body. The thickening of cream observed in the churn is a phenomenon

[1] Wisconsin Report, 1896, p. 73.

likewise dependent on these conditions. Temperature also has a marked effect, the consistency being increased or diminished as it is lowered, or raised.

Effect of physical agents

Heat.

It has previously been stated that variations in temperature have a marked effect on the consistency of milk and cream; that within moderate limits the effect is the same as with most viscous substances, it being made thinner when warmed, and the original consistency returning when cooled to the initial temperature.

Pasteurized milk and cream show an apparent exception to this rule, inasmuch as the original consistency does not return after the milk or cream is thoroughly chilled. This condition is a serious objection to the use of these products on the part of the consumer, as he invariably refers this relative thinness to a lack of butter-fat. So serious has this complaint become that it has greatly militated against the general introduction of these products. As this is the only objection, and as these products have every advantage from a sanitary and economic standpoint in comparison with ordinary milk and cream, this has been the chief incentive from the practical standpoint for undertaking this study.

Before attempting to find a remedy for this difficulty, it became necessary to study the general question of the conditions affecting the consistency of natural milk and cream when subjected to high temperatures such as are used in the pasteurizing and sterilizing processes.

Here the microscope gave us an important clue to the physical constitution of milk and cream that had been submitted to the action of heat. A microscopic examination of pasteurized milk or diluted pasteurized cream presents a very different picture from that of normal milk or cream. In the case of the

normal milk the fat globules, in place of being homogeneously distributed throughout the microscopic field, are grouped in part in irregular but well-defined masses. But not all of the fat globules are included in these fat aggregations. Some of the globules remain isolated and distinct, although there is a marked tendency in cover-glass preparations, owing to capillary currents, for these individual globules to be caught in these irregular groupings. The matrix that holds these fat globules together is under the microscope practically transparent, but by watching these currents with their floating fat globules, the irregular outline of the fat clots can be perceived. In these clots it will be observed that the individual fat globules retain their spherical form and do not coalesce, as is the case in incipient churning.

The nature of the substance that acts in the capacity of clot binders is not well understood. Babcock ascribed this effect to the presence of a small quantity of lacto-fibrin which he thought acted in a manner similar to blood fibrin. His proof for the presence of fibrin was not direct, although numerous physical and chemical reactions were noted that were identical with those found with blood fibrin.

The microscopic appearance of milk or cream that has been heated above 65° C. (149° F.) is totally different. Not only is this true with pasteurized milk, but sterilized or boiled milk as well as condensed milk likewise present a similar microscopic appearance. In these cases the fat globules are homogeneously distributed throughout the microscopic field. The fat aggregations that are so characteristic of the preparations of normal milk and cream are here entirely lacking.

Hundreds of preparations have been made of both pasteurized milk and cream from individual and mixed milks, and in no case have we found any exception to this condition. This phenomenon is certainly coincident with the change in consistency, and

we may reasonably expect that it is causally connected in some way with this microscopic appearance.

To prove this point more conclusively, it is necessary to study simultaneously, both from a microscopical and a viscometrical standpoint, milks that have been heated at different temperatures.

Experiments on this point were made, showing that the change in consistency did occur at practically the same temperature at which the microscopic clots in the milk broke down. This relation seems to show that the greater consistency of natural cream is very intimately connected with the presence of these fat aggregations. In milk this is less pronounced, owing to the greater effect that the serum solids have upon the total consistency of the fluid.

Centrifugal force.

It is a well-known fact to creamery men that cream taken from milk by the centrifugal cream separator is considerably thinner than that containing the same percentage of fat that is obtained by the gravity system. The cause of this has not yet been satisfactorily explained, but is generally attributed to the higher temperature and the fresher condition of the milk in the separator process.

A comparative microscopical examination of separator and gravity creams throws much light on this question. In every case the tendency toward grouping is greatly reduced in the separator cream, the fat globules often being as homogeneously distributed as in pasteurized cream. Frequently groups of globules are observed in separator cream that are due to incipient churning. These, however, can be readily distinguished from the normal fat aggregation because the globules are almost always distorted or coalesced. The thickening of cream in the churn is also probably due to something of this sort.

Effect of chemical agents

Acids.

When milk or cream is allowed to stand under conditions that favor bacterial development, the milk-sugar is gradually changed into lactic acid. The increasing acidity due to this change causes a gradual precipitation of the casein, at first in microscopic clots. In due time this finally forms a semi-solid coagulum as is seen in loppered or sour milk. The formation of these clots is accompanied by an increase in the consistency of the milk even before it shows signs of curdling. Although they have the same general effect in the milk, yet the formation of these incipient curd clots has no connection with the normal grouping of the fat globules. This explains undoubtedly the thickening of cream during the ripening, also, in part, the heavier body of gravity cream that is usually much older and more acid than separator cream.

This same result is reached when acid is artificially introduced into milk or cream, the only difference being that in the addition of commercial acid, the inability thoroughly to distribute it through the milk results in the formation of much larger curd clots. These clots inclose large numbers of fat globules, and have under the microscope a light yellow appearance which distinguishes them from the normal fat aggregation in which the matrix is transparent. Salts like magnesium sulfate that have the power of coagulating casein exert a similar effect.

Alkalies.

When caustic alkalies like sodium or potassium hydrate are added to milk, the consistency is increased. This increase is probably due to the formatiou of a soluble casein compound that augments the viscosity of the milk and cream, although at the same time the influenee of the fat is somewhat diminished, owing to dissolution of the fat aggregations.

Under the microscope normal milk treated with dilute solutions of these alkalies still shows the usual fatty aggregations,

although when milk is drawn directly into a solution of these alkalies, the grouping is entirely prevented. A satisfactory explanation of this phenomenon has not yet been found. Different alkalies and alkaline earths have been tried in this connection, but none of them has any effect on the microscopic appearance, except in the case of calcium hydrate, which increases the tendency of the fat globules to aggregate in a marked degree. The significance of this specific reaction will be considered in the succeeding article.

Conclusion

The consistency or body of milk and cream is due to:

1. The viscosity of the serum imparted by solids in solution.
2. The mechanical state of suspended substances (fat, etc.).

The casein exerts a greater influence on consistency than fat, and in milk is a chief factor; in cream the fat assumes a more important rôle because of its high percentage. The aggregations of fat globules also have a very important influence in determining the consistency of milk and especially cream.

THE SPECIFIC HEAT OF MILK AND MILK DERIVATIVES (Hammer and Johnson) [1]

In a great many dairy processes where heat is used, the amount and intensity of the energy necessary to gain a certain end-product are very important. These factors are important not only because heat, like material commodities, is an item of expense, but also because too great an intensity of temperature, or too prolonged an application, may cause serious chemical and physical changes in the substance worked with.

The amount of heat which it takes to raise unit weight of a substance unit temperature depends, first, upon its chemical nature and, second, upon its physical state.

[1] Iowa Research Bul. 14.

The ratio between the number of calories required to raise a given weight of a substance through a given temperature interval, and the number of calories required to raise the same weight of the standard substance through the same temperature interval is called the "specific heat" of the substance. Water is always the standard substance, and so the specific heat of a substance is the number of calories required to raise one gram or one pound one degree C. or F. respectively.

The heat capacity of a substance is obviously its specific heat multiplied by the quantity of the substance.

It is particularly important to bear in mind that the specific heat of a substance is not the same at all temperatures, though for most substances the changes are not great so long as the substance remains in the same physical state.

Persons interested in milk and milk derivatives who have to deal with great quantities of these materials upon narrow margins, both financially and in the matter of temperature control, face the necessity of a knowledge of all factors of any considerable magnitude.

In pasteurizing it is desirable to know the amount of heat required to bring a definite amount of milk or cream from the temperature at which it has been delivered or held up to the temperature used in pasteurizing, as well as the amount of refrigeration required to cool the same material down to a temperature satisfactory for storage or for inoculation. Although the losses which constantly occur, and which depend on a number of factors, prevent the exact computation of the amount of heat or refrigeration through a knowledge of specific heats alone, still, the exact experimental values are of great importance in calculating the cost of pasteurization, particularly when large quantities of material are being handled. The increasing use of pasteurization, both in plants selling milk, and in plants manufacturing butter or ice cream from pasteurized cream, makes the specific heat values of increasing importance. In calculat-

ing the cost of storing butter and hardening ice creams the respective specific heats are also essential.

M. Mortenson of the dairy section of the Iowa Agricultural Experiment Station has recently called attention to the importance of the specific heat of the mix in ice cream work. Aside from the question of cost of hardening, the specific heat of the mix is apparently of significance in its effect on the palate, the sherbets and low fat ice creams with a higher specific heat seemingly tasting colder than ice creams carrying considerable fat and accordingly having a lower specific heat.

Specific Heats of Milk and Milk Derivatives

Including heat required to melt fat if this factor enters

Value obtained from Curves, Plate V. Temperatures in Centigrade

	At 0°	At 15°	At 40°	At 60°
Whey	0.978	0.976	0.974	0.972
Skim-milk	0.940	0.943	0.952	0.963
Whole milk	0.920	0.938	0.930	0.918
15 per cent cream	0.750	0.923	0.899	0.900
20 per cent cream	0.723	0.940	0.880	0.886
30 per cent cream	0.673	0.983	0.852	0.860
45 per cent cream	0.606	1.016	0.787	0.793
60 per cent cream	0.560	1.053	0.721	0.737
Butter	(0.512)	(0.527)	0.556	0.580
Butter-fat	(0.445)	(0.467)	0.500	0.530

(For butter and butter-fat)

Values in parenthesis were obtained by extrapolation, under assumption that the specific heat is about the same in the solid and liquid states.

Specific heat of whole milk.

The samples of milk used in the tests were from the composite milk delivered at the College creamery. The fat-content varied from 3.4 per cent to 4.9 per cent, most samples having about

4.3 per cent. About fifteen hours elapsed between the time the milk was drawn from the cows and the time of the tests. After the milk was delivered at the creamery the samples were kept in the refrigerator.

Though the changes in the specific heat of milk between 15.0° C. and 60.0° C. are not great, still there is shown by our data a fairly pronounced maximum at about 30.0° C. Some of the reasons for this will be discussed later.

Specific heat of whey.

The whey used was from composite milk and was obtained from the cheese vat. There was present from 0.25 to 0.30 per cent fat and the samples were opalescent. The valnes obtained for two samples taken at different times were very near one another. The average specific heat between 23° and 33° C. was 0.975.

Specific heat of skim-milk.

Samples of sweet skim-milk varying in fat-content from 0.30 to 0.38 per cent were obtained from a small separator immediately after running through the machine. The average of fifteen determinations on four different samples made between approximately 20° and 40° C. gave an average value of 0.949. Over the pasteurizing range of 60–70° C. the average value of 0.963 was obtained.

Specific heats of cream.

The creams used were sweet and were separated from composite milk in the morning and kept in a refrigerator until evening, when the measurements were carried out. A series of determinations was made on each sample over quite a wide range and generally up to about 60° C.

In the conrse of the measurements on creams it was found that apparent specific heats considerably above 1.000 were often encountered. This peculiarity of cream was also noted by Fleischmann. The authors' data for 33.5 per cent, 30 per cent, 27 per cent, 15 per cent, and 60 per cent creams have been ob-

tained under very definite conditions and the results averaged, and shown in the form of curves.

Specific heat of butter.

Three samples of butter taken from the churning on three different occasions, and containing the ordinary amounts of curd, salt, water, and fat gave the following results:

SPECIFIC HEAT OF BUTTER

No.	Per Cent Salt	Per Cent Curd	Per Cent Water	Per Cent Fat	Av. Sp. Heat 30–60° C.
I	2.2	0.60	14.20	83.0	0.688
II	1.02	0.48	13.50	85.0	0.557
III	1.14	0.76	13.60	84.5	0.574

The values for ordinary butter are considerably higher than for pure fat. This is in part due to the presence of considerable quantities of water.

Specific heat of butter-fat.

Butter-fat carefully prepared in accordance with the specifications of the official method gave the following results:

SPECIFIC HEAT OF BUTTER-FAT

No. 1. Average from 30–60° C. equals	0.532
No. 2. Average from 30–60° C. equals	0.510
Average	0.521

Samples of practically pure butter-fat were also prepared by taking freshly churned butter, placing it in a large separatory funnel, and keeping it in a thermostat at 43° C. so as to allow the fat, curd, and water to separate by gravity. Water was added several times, shaken with the melted fat, and allowed to separate, and then drawn off. Next fused calcium chloride was added and the melted fat thoroughly dried, then filtered. The

average value between 30° and 60° C. for four samples thus treated was 0.507. At 30° C. it was 0.485 and at 60° C. 0.530.

FREEZING POINT OF MILK

Since the density of milk is greater than that of water, it freezes at somewhat lower temperatures. The exact temperature at which milk will freeze is dependent on the relation between the solids and the water it contains; the higher the percentage of solids present, the lower will be the temperature required to freeze it. The freezing point for milk of average composition is about 0.55° C. below that of water. The higher the water-content, the more nearly will the freezing point approach that of water.

ELECTRICAL RESISTANCE AND CONDUCTIVITY (Wilcox)

The electrical conductivity of milk depends upon the degree of dissociation of the salts which it carries in solution. The resisting power of milk ranges between 180 and 210 ohms. If water is added to milk, its resistance is increased. An accurate determination of the amount of dilution cannot be made by an electrical test for the reason that the resisting power of water varies with its salt content.

REFRACTIVE INDEX OF MILK (Wilcox)

The refractive power of milk varies greatly according to the composition. In normal milk the refractive index ranges from 1.3470 to 1.3515. A minimum of 1.3435 is very rarely observed.

CHAPTER V

THE TESTING OF MILK AND CREAM

THE value of milk either for direct consumption or for manufacture into various dairy products is largely dependent on its chemical composition. Since normal milk varies widely in composition, it is necessary to determine the relative amounts of the more important constituents in order to know its market value. A careful chemical analysis will give the most accurate data, but this method is too expensive and too slow for use in commercial work. The need for rapid methods for analysis has led to the development of many tests both in this country and in Europe. Many of these methods, while useful at the time, have been superseded by later ones and are no longer used. In commercial work, the constituents most commonly considered are the fat and the solids not fat or the total solids. In this country the percentage of fat is usually determined by means of the Babcock test. In Europe either the Babcock or Gerber method is used. The latter has not met with favor in this country because two reagents are required instead of one for the Babcock method. The percentage of solids is calculated by using the percentage of fat and the specific gravity as shown by the lactometer reading, in accordance with certain well-established formulæ.

Specifications for standard apparatus for use in the Babcock test have been worked out by the Official Dairy Instructors' Association and have been approved by the United States Bureau of Standards. They are as follows:

(Approved by Dairy Instructors' Assoc., 1916.)

I. Apparatus and Chemicals

Milk Test Bottle. 8 per cent 18-gram milk test bottle, graduated to .1 per cent. Graduation — The total per cent graduation shall be 8. The graduated portion of the neck shall have a length of not less than 63.5 millimeters ($2\frac{1}{2}$ inches). The graduation shall represent whole per cent, five-tenths per cent, and tenths per cent. The tenths per cent graduations shall not be less than 3 millimeters in length; the five-tenths per cent graduations shall be 1 millimeter longer than the tenths per cent graduations, projecting 1 millimeter to the left; the whole per cent graduation shall extend at least one-half way around the neck to the right and projecting 2 millimeters to the left of the tenths per cent graduations. Each per cent graduation shall be numbered, the number being placed on the left of the scale.

The maximum error in the total graduation or in any part thereof shall not exceed the volume of the smallest unit of the graduation.

Neck — The neck shall be cylindrical and of uniform internal diameter throughout. The cylindrical part of the neck shall extend at least 5 millimeters below the lowest and above the highest graduation mark. The top of the neck shall be flared to a diameter of not less than 10 millimeters.

Bulb — The capacity of the bulb up to the junction of the neck shall not be less than 45 cubic centimeters. The shape of the bulb may be either cylindrical or conical with the smallest diameter at the bottom. If cylindrical, the outside diameter shall be between 34 and 36 millimeters; if conical, the outside diameter of the base shall be between 31 and 33 millimeters, and the maximum diameter between 35 and 37 millimeters.

The charge of the bottle shall be 18 grams.

The total height of the bottle shall be between 150 and 165 millimeters ($5\frac{7}{8}$ and $6\frac{1}{2}$ inches).

Cream Test Bottle No. 1. 50 per cent 9-gram short-neck cream test bottle, graduated to .5 per cent. Graduation — The total per cent graduation shall be 50. The graduated portion of the neck shall have a length of not less than 63.5 millimeters ($2\frac{1}{2}$ inches). The graduation shall represent five per cent, one per cent, and five-tenths per cent. The five per cent graduations shall extend at least halfway around the neck (to the right). The five-tenths per cent graduations shall be at least 3 millimeters in length, and the one per cent graduations shall have a length intermediate between the five per cent and the five-tenths per cent graduations. Each five per cent graduation shall be numbered, the number being placed on the left of the scale.

The maximum error in the total graduation or in any part thereof shall not exceed the volume of the smallest unit of the graduation.

Neck — The neck shall be cylindrical and of uniform internal diameter throughout. The cylindrical part of the neck shall extend at least 5 millimeters below the lowest and above the highest graduation mark. The top of the neck shall be flared to a diameter of not less than 10 millimeters.

Bulb — The capacity of the bulb up to the junction of the neck shall not be less than 45 cubic centimeters. The shape of the bulb may be either cylindrical or conical with the smallest diameter at the bottom. If cylindrical, the outside diameter shall be between 34 and 36 millimeters; if conical, the outside diameter of the base shall be between 31 and 33 millimeters and the maximum diameter between 35 and 37 millimeters.

The charge of the bottle shall be 9 grams. All bottles shall bear on top of the neck above the graduations, in plainly legible characters, a mark defining the weight of the charge to be used (9 grams).

The total height of the bottle shall be between 150 and 165 millimeters ($5\frac{7}{8}$ and $6\frac{1}{2}$ inches), same as standard milk test bottles.

Cream Test Bottle No. 2. 50 per cent 9-gram long-neck cream test bottle, graduated to .5 per cent. The same specifications in every detail as specified for the 50 per cent 9-gram short-neck bottle shall apply for the long-neck bottle with the exception, however, that the total height of this bottle shall be between 210 and 235 millimeters ($8\frac{1}{4}$ and 9 inches), that the total length of the graduation shall be not less than 120 millimeters, and that the maximum error in the total graduation or in any part thereof shall not exceed 50 per cent of the volume of the smallest unit of the graduation.

Cream Test Bottle No. 3. 50 per cent 18-gram long-neck cream test bottle, graduated to .5 per cent. The same specifications in every detail as specified for the 50 per cent 9-gram long-neck bottle shall also apply for the 18-gram long-neck bottle, except that the charge of the bottle shall be 18 grams. All bottles shall bear on top of the neck above the graduation, in plainly legible characters, a mark defining the weight of the charge to be used (18 grams).

Pipette, capacity, 17.6 c.c. Total length of pipette not more than 330 millimeters ($13\frac{1}{4}$ inches). Outside diameter of suction tube 6 to 8 millimeters. Length of suction tube 130 millimeters. Outside diameter of delivery tube 4.5 to 5.5 millimeters. Length of delivery tube 100 to 120 millimeters. Distance of graduation mark above bulb 15 to 45 millimeters. Nozzle straight. To deliver its contents when filled to the mark with water at 20 degrees Centigrade, in five (5) to eight (8) seconds. The maximum error shall not exceed five one-hundredths (.05) cubic centimeter.

Acid Measure, capacity 17.5 c.c.

Cream Testing Scales, sensibility reciprocal of thirty milligrams, *i.e.* the addition of thirty milligrams to the scales, when loaded to

capacity, shall cause a deflection of the pointer of at least one division on the graduation.

Weights, 9 gram weights for 9-gram cream test bottles and 18 gram weights for 18-gram cream test bottles, preferably stamped correct by the U. S. or State Bureau of Standards.

Tester. Standard Babcock test centrifuge and speed indicator.

Dividers, for measuring fat column.

Water bath for cream samples, with proper arrangement for regulating and recording temperature of samples.

Water bath for test bottles, of sufficient size and with necessary equipment to insure proper control of temperature. The following dimensions for a twenty-four (24) bottle water bath are recommended: Metal box, 14″ long, 11″ wide and 8½″ deep and equipped with a bottle basket 9½″ long and 6½″ wide, capacity 24 bottles, a steam and water inlet, a drain, a thermometer holder with thermometer.

Commercial Sulfuric Acid, specific gravity 1.82 to 1.83.

Glymol, or white mineral oil, high grade.

ACCURACY OF THE GLASSWARE

It is essential that the graduations on the test bottles and pipettes be as accurate as possible. Many states require that all Babcock glassware be calibrated by a state official before it can be used in commercial work. Several methods have been devised for this work. A simple method is thus described by Van Slyke:[1]

"The quickest method of testing the accuracy of the scale of a test bottle is to use a special device, which is essentially a simple brass plunger (Fig. 5). This instrument is divided into two equal portions, each part being made of such a size as to displace exactly one cubic centimeter of liquid. This bottle-tester is used as follows: The test bottle is filled to the zero mark with milk, or one may use water or, better, wood alcohol, imparting color to the water or alcohol by adding some black aniline or carmine ink. Fill the bottle nearly to the zero mark and then finish with a pipette or dropper, adding a

[1] Modern Methods of Testing Milk and Milk Products, p. 45. Orange Judd Co.

drop at a time just to the mark. Any drops of liquid adhering to the inside walls of the neck must be removed, using conveniently a strip of blotting or filter paper. The tester is then slowly lowered into the neck of the test bottle until the liquid rises halfway between the two sections of the instrument, when the upper surface of the liquid should be at the 5 per cent mark, if the scale is correct to this point. If the surface of the liquid is above or below the 5 per cent mark, then the scale is incorrect to that extent. After the accuracy of the 5 per cent mark is tested, the instrument is then lowered into the bottle until the liquid rises about one-eighth of an inch above the top of the upper section of the tester. If the upper surface of the liquid is level with the 10 per cent mark, the graduation is correct at that point. The graduation of the scale is regarded as correct, if the tester shows the 5 and 10 per cent marks to be correct.

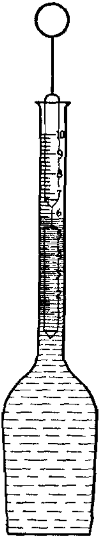


FIG. 5. — Device for testing accuracy of milk-bottle.

"In explanation of the use of this form of bottle-tester, it is to be remembered that the neck of the milk bottle is so graduated as to hold 2 c.c. between the 0 and 10 marks; hence, the volume between the 0 and 5 marks should be 1 c.c. and that between the 5 and 10 marks should be also 1 c.c. The brass plunger is so made that each section displaces, or forces up into the neck, 1 c.c. of liquid, the whole instrument displacing 2 c.c. This tester therefore gives two tests of the scale, one at the 5 per cent mark and the other at the 10 mark.

"Some of these instruments are made to test the 4 and 8 per

cent points, so that with two testers, one can, if desired, test the accuracy of the scale at the 4, 5, 8, and 10 points. There are also testers of the same form made for cream bottles.

"In using this bottle-tester, the following precautions are to be observed:

"(1) Have the upper surface of the liquid exactly on a level with the zero mark in the neck of the test bottle before putting the tester in.

"(2) Clean the inside walls of the neck of the bottle from adhering liquid before testing.

"(3) No air-bubbles should be allowed to adhere to the tester when it is below the liquid.

"(4) The tester should be dry each time before using."

A special burette has been devised at the University of Wisconsin [1] by which the amount of error can be read directly from the neck of the test bottle, in percentage rather than in cubic centimeters.

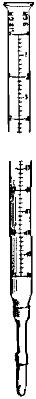


FIG. 6.—A burette which shows error in percentage rather than in c.c.

"This burette (Fig. 6) has two sets of graduations, one designed for bottles for 18-gram and the other for 9-gram samples, as in the case of the 50 per cent 9-gram cream bottle. The bore of the burette is so small that the space from 0 to 10 (on the 18-gram scale) is approximately $7\frac{1}{4}$ inches. It has a capacity to deliver 2 c.c. The length of the graduations on the neck of an ordinary 18-gram test bottle, reading 0 to 10, is approximately $2\frac{3}{4}$ inches. The graduations on the burette occupy a length of approximately 18 inches from 0 to 25 on the 18-gram scale. It will deliver 5 c.c. The graduation on the 9-gram scale is necessarily twice as large as on the 18-gram scale. As the

[1] Wisconsin Bul. 241.

graduation from 0 to 50 occupies approximately 18 inches, it is readily seen that closer reading can be made than with the 9-gram six-inch 50 per cent cream bottle the scale of which occupies approximately $2\frac{3}{4}$ inches.

"In order to aid in reading the burette, the per cent lines on the 18-gram scale extend entirely around it. By means of these lines the operator can easily bring his eye to the level of the liquid, which is a matter of great importance when accurate work is desired. Such a burette can be constructed so that the capacity of the bore is a definite number of cubic centimeters, or that it will deliver a definite number of cubic centimeters, allowing a certain number of seconds, say ten, for the alcohol to flow down the sides. The first way is preferable when mercury is used as a calibrating reagent, but as this reagent offers many difficulties, it is better to construct the burette on the basis of its delivery, allowing a certain period of time to elapse before taking the readings."

Reagents used in calibrating.

"For calibrating purposes denatured alcohol is very suitable. In accurate work it is well to color this dark so that the meniscus is not visible. This can be done by dissolving a small quantity of black dye in cold water and then boiling the mixture for five or six minutes until all the dye is dissolved. When cool, a sufficient amount of the solution can be added to the denatured alcohol so that the meniscus is not visible."

How to use the burette.

"To calibrate glassware with the burette it is necessary to fill the test bottles with the colored alcohol exactly up to the zero mark. This can be readily done where a number of bottles are to be calibrated by filling them approximately up to the zero mark: within a short time the necks of the bottles will be dry and then, by means of a medicine dropper, enough alcohol may be added to bring the liquid exactly to the zero mark."

In order to do accurate work with any burette where a pinch-

cock is used, it is of the greatest importance that no air is allowed to remain in the small rubber tube at the bottom of the burette.

Burettes having a small bore can best be filled by inserting the lower part in the reagent and drawing it up slowly by means of the mouth or by using a rubber bulb.

By having the liquid in both burette and bottle at zero, it is an easy matter to draw the liquid of the burette slowly into the test bottle. Observations may be made at any point, providing sufficient time is allowed for the liquid to flow down the side of the burette. The correct reading is always given directly by the burette. If, for example, the burette reads 25, 30, or 40 per cent, the reading on the neck of a calibrated cream bottle should also be 25, 30, or 40 per cent. If the burette reads 25.5 or 30.5 and the bottle reads 25.0 or 30.0, it is evident that the bottle reads one-half per cent too high.

TESTING MILK FOR BUTTER-FAT BY THE BABCOCK METHOD (Hunziker)

Sampling the milk

The sampling is the most important operation of the test. Unless the sample is representative of the milk from which it is taken, the result of the test cannot be correct. The fundamental cause of non-representative samples lies in the fact that the butter-fat is lighter than the remainder of the milk constituents. When the milk is allowed to lie in the cans undisturbed, the butter-fat rises to the surface. Unless the milk is thoroughly mixed before sampling, a representative sample cannot be taken.

Single samples of milk.

The most accurate and reliable method of sampling is to take single samples of each patron and test them daily. In order to minimize the work, the sample may be pipetted from

the properly mixed milk in the weigh can direct into the Babcock test bottle. In this way the extra work of handling sample jars and of preparing the milk in the jar for the test is made unnecessary, and all danger of fat separation before the sample reaches the test bottle is avoided.

Another practice of taking single samples is to take and test samples from every other or every third delivery of milk. At the end of the month or other period of payment, these individual tests are averaged and the pounds of butter-fat are calculated by multiplying the average test by the total pounds of milk received for that period. This practice is obviously less reliable than where single samples are taken and tested daily. However, experimental results indicate that samples taken as often as every third day give results which compare very closely with those obtained from daily samples.

Composite samples of milk.

The purpose of taking composite samples is to reduce the labor and expense of testing. The true composite sample consists of aliquot portions of milk of several deliveries from the same patron.

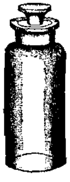


FIG. 7. — Glass-stoppered milk sample bottle.

FIG. 8. — Milk sample bottle with metal cap.

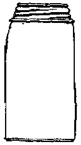


FIG. 9. — Mason fruit jar for milk samples.

Jars for composite sampling (Figs. 7–9).

Composite sample jars must have a tight seal in order to prevent evaporation of moisture. Pint jars sealed with glass

stoppers, cork stoppers, metal caps, or screw tops may be used for this purpose. Bottles with paper caps and jelly glasses with tin lids do not furnish tight seals; they should not be used for this purpose.

A separate jar is used for each patron, and each jar must bear the respective patron's number. The jars should be thoroughly clean and, in order to guard against errors, they should be arranged on convenient shelves near the weigh can in numerical order, grouping the jars of patrons of the same route together.

Taking composite samples (Fig. 10).

Correct composite samples may be obtained by the use of a milk thief or a graduated pipette. If the milk thief is used, it is inserted into the weigh can of the entire delivery of one patron. The milk in the tube rises to the level of the milk in the weigh can. The milk thief is then emptied into the sample jar. In case the graduated pipette is used, a certain quantity of milk is taken for every pound of milk delivered by the patron (usually about .1 c.c. for every pound of milk delivered). The milk thief is the handier instrument of the two, but where the amount of milk delivered by different patrons varies considerably, the samples of milk from the larger milk producers are often too large to be practical.

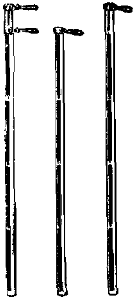


FIG. 10. — McKay milk sampler or thief.

Other so-called composite samples are taken by using the same measure for all milk receipts. In this case a small dipper holding about one ounce is generally used. With this dipper a sample of milk is taken daily from the weigh can of each patron's milk and transferred into the sample jar. This method of composite sampling is not mathematically correct and the results tend to be less reliable, although experimental data

show that the results average practically the same as where aliquot portions are taken.

Objection to composites.

The chief objection to composite samples of milk is that the composite samples are usually held too long before testing. This causes a more or less complete separation of the butter-fat in the form of a thick and tough layer of cream. This cream mixes with difficulty back into the remainder of the sample so that the portion transferred to the test bottle is often not representative of the true richness of the milk. This defect is especially pronounced where the samples are not protected against high temperature (summer heat).

Composite samples of milk should be held for not longer than one week and tested at the end of that period.

Care of the milk sample

The milk sample should be in as normal condition as possible at the time of testing, otherwise it will be difficult to pipette a representative portion into the test bottle. This difficulty is entirely avoided where the sample is transferred with the 17.6 c.c. pipette from the weigh can direct to the test bottle. The changes which the improperly kept sample undergoes are caused by evaporation and by fermentation.

Evaporation causes the percentage of fat and other solids to increase, yielding misleading tests. It also tends to dry the milk on the surface, causing the formation of a tough, leathery layer. In this condition it is difficult to secure a representative portion for the test. This can be prevented by giving the sample jar a gentle rotary motion after each addition of milk, by properly replacing the cap or stopper after each addition of the milk, by protecting the sample from excessive heat, and by testing at least once a week.

Fermentation causes the milk to spoil, and the milk usually

becomes curdy and moldy. In this condition it cannot be properly pipetted into the test bottle unless specially treated. Fermentation can be prevented by starting the composite sample with a clean bottle, preventing the slobbering of the milk over the outside of the bottle, and adding a small amount of a preservative, such as corrosive sublimate, potassium bi-chromate, or formaldehyde.

Corrosive sublimate tablets are the most convenient and least objectionable form of preservative. Use one tablet in each bottle. Put it into the sample at the time the first portion of the composite sample is taken. Shake the bottle by giving it a rotary motion until the tablet is dissolved. After each addition of milk to the bottle, shake again, giving the bottle a rotary motion until the contents are thoroughly mixed. This precaution has the further advantage of preventing the formation of a tough layer of cream and facilitates the preparation of the sample for the test. One preservative tablet preserves one pint of milk for about two weeks. When purchasing preservative tablets from creamery supply houses, ask for large-sized corrosive sublimate tablets. It is advisable to crush the tablet before dissolving, in order to avoid the need of excessive agitation which tends to churn a portion of the fat.

Preparation of sample for the test

Before testing, the samples should be brought to the proper temperature; this may range from 55 degrees to 70 degrees F. If the samples have been exposed to summer heat or to temperatures near the freezing point, the sample bottles are best set into a tank, sink, or tub and allowed to stand in water at about 60 degrees F. until the temperature of the milk is neither below 55 degrees F. nor above 70 degrees F.

The contents of each bottle must be thoroughly mixed before pipetting into the test bottle. If the composite sample

has received the proper care, as directed on page 112, the gentle shaking of the sample bottle and the pouring of the contents from one bottle to another several times should be sufficient.

Samples containing lumps of cream or granules of butter cannot be tested properly without extra preparation. They should be heated to at least 110 degrees F., or until all lumps of butterfat have melted and disappeared; they should then be shaken vigorously and pipetted into the test bottle at once. Even with this precaution it is difficult to transfer to the test bottle a representative portion from such a sample.

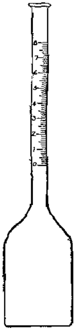


FIG. 11. — The standard milk test bottle is graduated to 8 per cent with subdivisions of .1 per cent.

Sour and curdy samples should be treated as follows: add one-half teaspoonful of soda lye or potash lye, shake, and let stand until all lumps of curd have disappeared. The sample is then ready for the test. When testing samples to which soda lye or other alkali has been added, the acid should be added slowly and carefully to avoid accidents and to prevent the loss of a portion of the contents of the bottle by excessive effervescence.

Milk test bottles (Fig. 11)

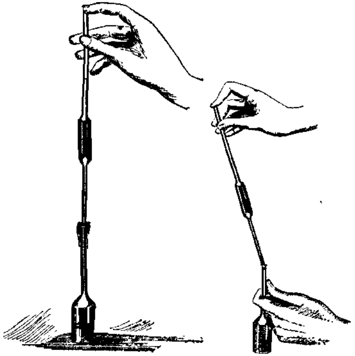
The standard milk test bottle is the 8 per cent bottle. This bottle is graduated to .1 per cent. The main divisions represent 1 per cent. The figures are located at the left of the graduation. For detailed specifications for "Standard Milk Test Bottles" see Agricultural Experiment Station Circular No. 41.

Measuring the milk into the test bottle (Figs. 12, 13)

Use a standard 17.6 c.c. pipette and a standard 8 per cent milk test bottle. Draw the milk from the properly prepared

sample into the pipette and fill the pipette to the 17.6 c.c. mark. Discharge the pipette into the test bottle. In order to do this rapidly and to prevent spilling, drop the discharge end of the pipette into the neck of the test bottle until the bulb of the

FIG. 12.—The 17.6 c.c. standard pipette for milk.



The wrong way *The right way*

FIG. 13.—Manner in which the tests should be transferred to the bottle.

pipette rests on the neck of the bottle, then release the milk. Blow the last drop of milk out of the pipette before removing it from the bottle. Mark each bottle with a number corresponding with the name or number of the respective patron on the test sheet. The marking is best done with a lead pencil.

Adding acid (Figs. 14, 15)

Use commercial sulfuric acid, specific gravity 1.82 to 1.83. The temperature of the acid should be the same as that of the

milk, 55 degrees F. to 70 degrees F. In order to insure the proper temperature of the acid it is advisable to set the acid bottle into the tank containing the milk sample bottles.

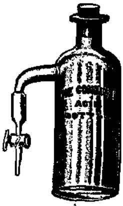


FIG. 14. — The combined acid bottle for rapid work.

FIG. 15. — The 17.5 c.c. acid cylinder.

Add 17.5 c.c. of acid to the milk in the test bottle and mix by giving the bottle a rotary motion until the lumps of curd are completely dissolved and the mixture presents a black color. It is advisable to add the acid in about three installments, shaking the bottle after each addition. Attention to this precaution helps to secure clear tests.

Whirling and adding water (Figs. 16–21)

Set the test bottles into the Babcock centrifuge. If the test bottles containing the mixture of milk and acid are held over and allowed to become cool, they should be heated by setting in hot water before whirling.

Steam turbine and electric driven testers with not less than twenty-four pockets are best adapted for factory use.

FIG. 16. — In pouring acid into the test bottle, incline the bottle a little, to avoid spilling acid on the hand.

FIG. 17. — To mix the acid and milk whirl the bottle in a circle until the contents are of a uniform brown color.

They are constructed of two general sizes, — those having a twelve-inch diameter wheel and those having an eighteen-inch diameter wheel.

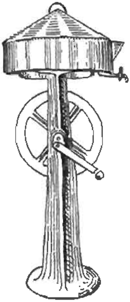


FIG. 18. — The original Babcock tester.

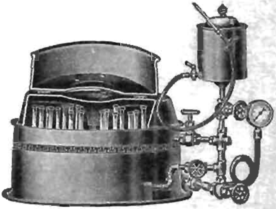


FIG. 19. — The Babcock tester — "Facile"

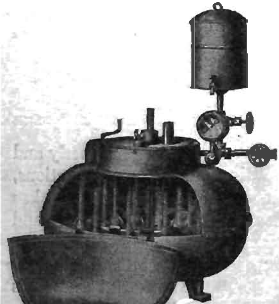


FIG. 20. — The Babcock tester — "Wizard"

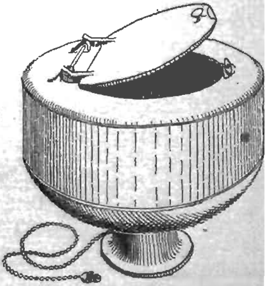


FIG. 21. — The Babcock tester — "International"

Whirl for five minutes at the proper speed. A tester with a twelve-inch wheel requires one thousand revolutions and a tester with an eighteen-inch wheel requires eight hundred revolutions a minute.

Fill the bottles to the bottom of the neck with hot, soft water; whirl again for two minutes and fill the bottles with hot, soft water to about the 7 per cent mark; whirl for one minute. The temperature of the water added should be not lower than 140 degrees F. and preferably near that of boiling water (212 degrees F.).

Reading the test (Fig. 22)

Place the test bottles in a water bath at 135 degrees to 140 degrees F. for five minutes. Measure the fat column with a pair of dividers, including the meniscus or curve, both at the bottom and at the top of the fat column. Each subdivision represents .1 per cent; each main division represents 1 per cent. Record the percentage of fat thus found on the test sheet.

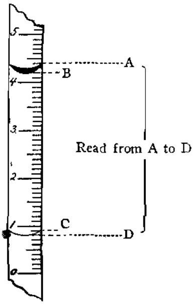


FIG. 22.—How the milk test should be read.

Abnormal appearance of the fat column

When the test is made properly and in accordance with above directions, the fat column is perfectly clear, has a golden yellow color, and the top and bottom curves are sharply defined.

The presence of whitish curd in or immediately below the fat column is the result of excessively cold milk and acid, or the use of too little or too weak acid.

The presence of charred and dark curdy masses in the fat

column is caused by too warm milk and acid, or too much or too strong acid.

Such tests should be rejected, as the readings of the same are prone to be inaccurate.

The appearance of foam on the surface of the fat column is caused by the use of hard water. The carbonates, when acted on by the sulfuric acid, break down, liberating carbon dioxide gas which, rising through the fat column, gathers on its surface in the form of air bubbles. Where soft water, distilled water, or rain water is not available, the water may be softened by boiling it or by the addition to it of a few drops of sulfuric acid before use.

CREAM TESTING (Hunziker)

Sampling the cream

One of the most common causes of incorrect cream tests lies in the inaccuracy of the cream sample. The difficulty of securing accurate cream samples is greatly augmented by the fact that the cream, at the time of sampling, is often in no condition to be sampled correctly.

Care of the cream on the farm.

In order to facilitate accurate sampling by the cream hauler, shipping station agent, or creamery, the cream should receive the proper care on the farm. The separator should be thoroughly cleaned after each separation and the cream screw or skim-milk screw so set as to discharge cream containing about 35 to 45 per cent fat. After separation the cream should be cooled and kept cool. This is best done by setting the cans containing it into a trough or tank of cold water. The cream cans should remain in the cold water until they leave the farm. The cream should be stirred occasionally to prevent excessive separation of the fat and the drying of the cream on the surface.

Sampling by the cream hauler (Figs. 23-27)

Where the cream is gathered at the farm by the cream hauler, the creamery should see to it that its haulers or agents have the necessary equipment and be given proper instructions for taking samples right. The equipment should consist of a

FIG. 23. — Scale for weighing cream.

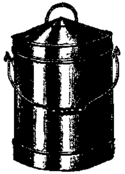


FIG. 24. — Pail for weighing cream.

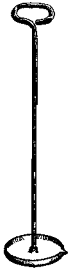


FIG. 25. — Cream stirrer and sampler.

spring scale, capacity not less than sixty pounds, for weighing the cream; a weighing pail in which each farmer's cream is weighed separately; a combined stirrer and sampler properly constructed; a rubber scraper for scraping the cream from the sides and bottom of the farmer's pail or can and from the weigh pail after each weighing; a set of properly numbered sample bottles with tight stoppers or screw tops and arranged in a rack in numerical order; cans, preferably ten-gallon cans, into which to empty the weigh pail; and a cream report book. The cream should be thoroughly stirred with the stirrer, until it is completely mixed, then poured into the weigh pail, weighed, and sampled. The mixing may be made more thorough by pour-

ing the cream from one pail to another several times. The scales should not be held up by hand, but should be suspended from a stationary hook, preferably attached to the rear of the wagon. After pouring the cream into the large can, the weigh pail should be thoroughly scraped with the rubber scraper, removing the remnants of cream that adhere to the sides and bottom of this pail. The sample bottles, after filling, should be sealed tightly and returned to their places in the rack. In case the weigh pail does not hold all the cream of one patron, a separate sample should be taken from each weighing and the corresponding weights recorded.

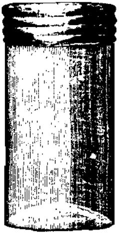


FIG. 26. — Screw-top cream sample jar.

Where the cream of each patron is sampled at the creamery or shipping station, the same precautions should be observed. The mixing is best accomplished by pouring or stirring. In order to facilitate the pouring, to save time, and to prevent unnecessary loss by spilling, a few straight-walled cans with the tops entirely open should be provided. These cans should be large enough to easily take care of the contents of a ten-gallon can without overflowing. When the cans are not too full, thorough mixing is permissible by stirring, provided that a stirrer with a good-sized disk and a stout rod, not less than thirty inches long and with a good hand hold, be used. When the cream is mixed by stirring, the stirring must be done thoroughly; simply giving the cream a few dips with the sample dipper is not sufficient. The stirrer must be worked to the bottom of the

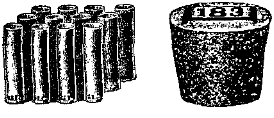


FIG. 27. — Cream sample tubes and cork stopper with numbered metal tag.

can several times and the entire contents of the can must be thoroughly agitated. Thick cream should be warmed until it pours readily; frozen cream should be warmed until the icy portions have completely disappeared. Churned cream cannot be sampled accurately. Its fat-content may be calculated by testing the buttermilk and estimating the amount of butter.
Composite samples of cream.

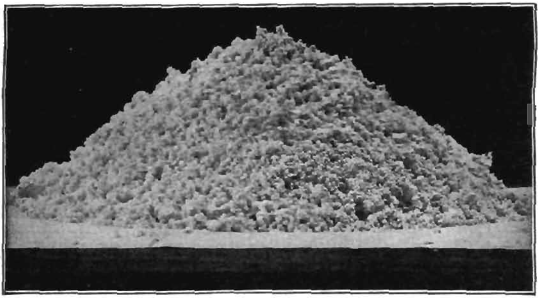
Composite samples of cream are not permissible. They are exceedingly difficult to obtain and are prone to give misleading results.

Care of the cream sample

The cream samples are in the best condition for testing immediately after sampling or as soon as they arrive at the factory. Samples which are not tested upon arrival at the creamery or soon after should be placed in the refrigerator until ready for the tester. The cream sample bottles or tubes should be sealed tightly; screw top seals or cork stoppers answer the purpose.

Preparation of the cream sample for the test

Samples of fresh cream of normal richness, and which is not perceptibly separated, can be tested accurately without special preparation, other than mixing thoroughly by shaking or pouring before use. Thick and semi-solid samples which are otherwise in good condition should be warmed to about 90 degrees F., then poured gently and weighed at once. Cream samples in which the butter-fat is completely separated and churned, or has formed a compact, tough, and leathery layer, as is the case with old samples not stored at a low temperature, should be heated high enough to melt the butter-fat, 110 degrees F. or above, then shaken thoroughly and weighed out at once. It should be understood that samples in this condition are at



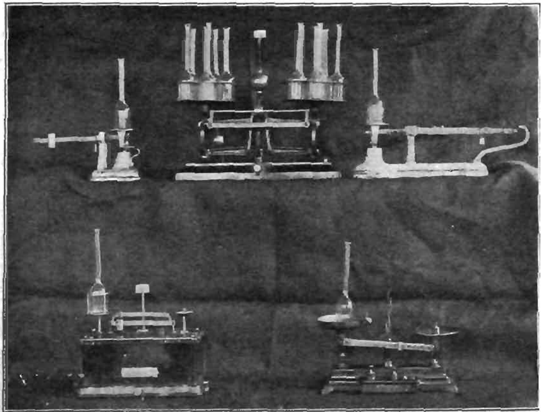


PLATE III. — Granular butter at end of churning process. See page 254.

Types of cream scales.

best difficult to handle and tend strongly toward inaccurate results.

Weighing the cream into the test bottle

The cream must be weighed into the test bottle, not measured. This is necessary in order to secure the correct amount by weight. Cream varies in weight with its richness and its mechanical condition, and no one measure will hold the correct amount of cream of varying richness. The correct amount of cream by weight is 9 grams.

Cream scales (Plate III).

The cream scales must be accurate and sensitive to at least $\frac{1}{10}$ gram; they should rest on a firm and level table, be properly adjusted, and kept in good working order.

Balances of large capacity and holding a large number of bottles are not as sensitive as balances of small capacity and holding a few bottles only. Other factors being the same, the one-bottle scale is the most accurate scale. However, two-bottle, four-bottle, and even twelve-bottle scales, if properly constructed, in good working condition and operated carefully, answer all practical purposes; they are sufficiently sensitive for this work, and their relatively large capacity simplifies the cream testing problem and avoids unnecessary expense.

The balances should be kept dry and protected from corrosive influences such as sulfuric acid, salt, etc. During operation the scales should not be exposed to drafts, and the weighings must be made accurately. After the bottles are placed on the scales, the scales should be properly balanced before any cream is transferred into the bottles. If any cream is spilled on the balance, it should be removed before the weighing is completed. Mark each bottle with a number and record this number on the test sheet opposite the name or number of the respective patron.

Cream test bottles (Figs. 28, 29)

Use standard 9-gram 50 per cent cream test bottles. The divisions represent .5 per cent, 1 per cent, and 5 per cent. The 5 per cent divisions bear a figure to the left of the graduation. Two styles of these bottles may be used, short-neck bottles and long-neck bottles. For further details regarding standard cream test bottles see Agricultural Experiment Station Circular No. 41.

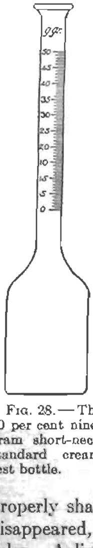


FIG. 28.—The 50 per cent nine-gram short-neck standard cream test bottle.

Adding the acid

Commercial sulfuric acid, specific gravity 1.82 to 1.83, should be used. The amount of acid to be used varies with the temperature and richness of the cream, averaging about 8 to 12 c.c. The most satisfactory guide, indicating the amount of acid needed, is the color of the mixture of acid and cream immediately after shaking. Add acid until, when properly shaken and all the white curd has disappeared, the mixture has a coffee-brown color. A light brown color shows that more acid is needed. A black color immediately after shaking indicates too much acid.

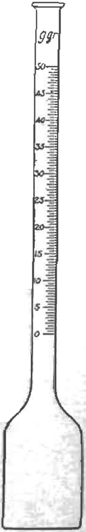


FIG. 29.—The 50 per cent nine-gram long-neck standard cream test bottle.

When adding the acid, the bottle should be held in an inclined position and should

be revolved once. In this way the acid washes the neck free from particles of cream and curd.

After the acid is added the bottle should be shaken carefully by giving it a rotary motion. Care should be taken not to spill any of the contents. In case of spilling, the test should be rejected and made over.

Whirling and adding water

The bottles are now ready for the Babcock centrifuge. If there are not enough test bottles to fill all the pockets in the tester, the bottles should be so arranged as to balance the machine. Whirl for five minutes at the proper speed; one thousand revolutions per minute for a tester with a twelve-inch diameter wheel and 800 revolutions a minute for a tester

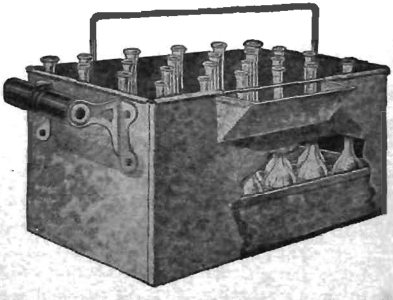


FIG. 30.— Water bath for bringing test bottles to proper temperature before reading.

with an eighteen-inch diameter wheel. Fill to the bottom of the neck of the bottles with hot, soft water, whirl for two minutes; fill to about the 45 per cent mark with hot, soft

water and whirl one minute. The temperature of the water added should be not less than 140 degrees F., and preferably near that of boiling water.

Reading the test (Figs. 30–32)

Remove the bottles from the tester to the water bath, where they should remain in water at a temperature of 135 degrees to 140 degrees F. for ten minutes. Just before reading the test and when taking the bottles from the water bath, add a few drops of glymol. The glymol removes the meniscus or curve on top of the fat column, leaving a straight line which is sharply defined and readily seen.

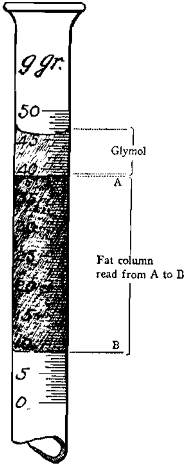


Fig. 31. — Method of reading the cream test.

Measure the fat column and record the percentage of fat on the test sheet, opposite the test bottle number of the respective patron.

Purpose and use of glymol (Figs. 33, 34)

Glymol is a high quality of white mineral oil. It is slightly lighter than butter-fat and therefore floats on top of the fat column.

The object of using glymol is to remove the meniscus or curve present at the top of the fat column. This curve, owing to refraction of the light, is indistinct and renders

Fig. 32. — Dividers assist in reading the cream test.

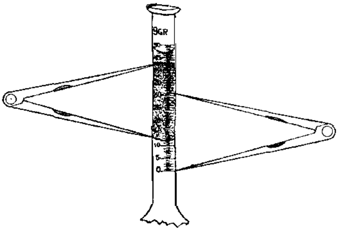


FIG. 33.—Glymol removes the meniscus from surface of fat and facilitates accurate reading.

correct reading difficult. When a few drops of glymol are placed on top of the fat column, the meniscus disappears and a straight, sharply defined line is formed between the top of the fat and the bottom of the glymol. In this condition the test can be read easily and accurately.

The glymol is best kept in a small bottle equipped with a perforated cork. The opening in the cork carries a glass tube, the lower end of which reaches to near the bottom of the bottle. In order to transfer the glymol to the test bottle, press the forefinger over the top of the glass tube. Raise tube and run the glymol from the tube, along the side of the neck of the test bottle, on the top of the fat column. If poured direct on the fat column, it tends to slightly mix with the butter-fat, causing the surface of the fat column to be ragged and indistinct. A few drops of glymol (about $\frac{1}{2}$ to 1 c.c.) are sufficient. For the best results the glymol should be added immediately before reading. The glymol may also be conveniently transferred to the test bottle from a pipette or burette.

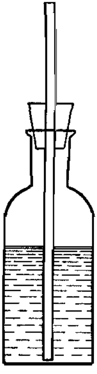


FIG. 34.—Glymol bottle with tube.

In case glymol is not available, the test should be read by including one-third of the

meniscus in the reading. Glymol should be used in the reading of the cream test only; the milk test should be read without the use of glymol. If glymol were used in the reading of the milk test, the results would be too low. Experimental results have indicated that in the milk test the meniscus compensates for the loss of residual fat. It therefore must be included in the reading.

Glymol may be purchased in drug stores. Ask for white mineral oil.

Coloring glymol

Some operators prefer the use of colored glymol. Glymol is best colored with alkanet root, which gives it a bright cherry color. Use one ounce of crushed alkanet root to one quart of glymol. Wrap the alkanet root in a small piece of cheesecloth and drop it into the vessel containing the glymol. The alkanet root may be removed from the glymol after twenty-four to forty-eight hours.

Alkanet root is sold by druggists at about twenty-five cents a pound.

Abnormal appearance of the fat column

If the test has been made properly and in accordance with above instructions, the fat column is clear and has a golden yellow color.

Milky curd in and immediately below the fat column shows that not enough or too weak acid was used. A charred and dark curdy fat column indicates the use of too much or too strong acid. Abnormal tests should be rejected, as the reading usually is indistinct and misleading.[1]

[1] For directions for avoiding the presence of foam on the surface of the fat column, see "Abnormal Appearance of the Fat Column" on page 118.

TESTING SKIM-MILK AND BUTTERMILK (Hunziker) (Fig. 35)

For testing skim-milk and buttermilk use bottles with double necks, which are especially constructed for this purpose. The graduation of these bottles varies somewhat with the make of bottle. In some bottles the total graduation is .25 per cent and

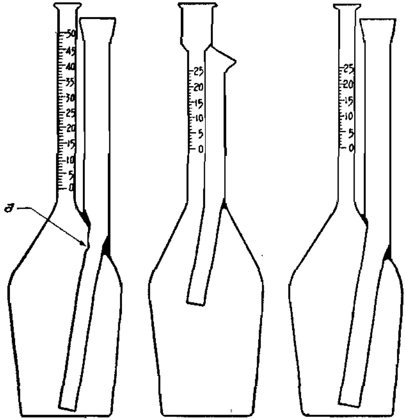


FIG. 35.— Different styles of skim-milk test bottles.

the subdivisions represent .01 per cent. In others the total graduation is .5 per cent and the subdivisions represent .05 per cent.

Measure the liquid into the test bottles with the 17.6 c.c. pipette used for milk testing. In the case of buttermilk, particularly that derived from pasteurized, sour cream, the buttermilk should be stirred very thoroughly before sampling. This

is necessary because the curd, which contains the bulk of the fat, separates out very quickly.

The test is completed in the same manner as that of milk, with the following modifications:

Special attention should be given when the bottles are placed into the tester. Test bottles in which the lower end of the funnel-neck extends perpendicularly along the side of the bulb to the bottom of the bottle, should be so placed that the funnel-neck faces the center of the tester, otherwise the fat rises into the funnel-neck. Test bottles in which the lower end of the funnel-neck extends diagonally to the bottom of the bottle should be so placed that the graduated neck faces the center of the tester. This will prevent excessive breakage of this type of bottles. The tester should run perfectly smooth in order to prevent excessive breakage, as these bottles are of very delicate construction.

Use about 20 c.c. of acid instead of 17.5 c.c. and whirl the bottles about twice as long as in the case of milk.

The amount of fat in skim-milk and in buttermilk is, or should be, so minute, the fat globules are so small, and the construction of the bottle is so crude, that it is difficult to secure very accurate tests of skim-milk and buttermilk.

The results of testing skim-milk and buttermilk should not be relied on absolutely for accuracy, but they may serve as a convenient guide, showing the operator whether these by-products contain comparatively little or much fat. The above suggestion is offered on the basis of the results of a vast number of skim-milk and buttermilk tests conducted by this department. In these tests the results were compared with the chemical fat estimations.

TESTING FROZEN MILK (Ross)

Partly frozen milk should never be sampled for testing, since a sample of such milk will not be representative. Such

milk should be melted and carefully remixed before any is removed for testing, but in melting the ice a temperature of not over 85° F. should be used. Too high a temperature is likely to cause a separation of the fat in the form of an oil, and when the fat thus separates it is almost impossible to remix it evenly with the milk.

If milk is allowed to stand for any length of time before freezing, the fat will rise to the surface and form a cream line. If the cream line thus formed freezes, the ice will be rich in fat.

If milk is agitated while freezing, the ice formed will be lower in fat-content, and the liquid part of the milk richer in fat than it should be. Milk is frequently delivered to milk stations and creameries in a partly frozen condition; and if a sample is taken for testing, it will give a higher fat reading than would be shown in a mixed sample of the milk. The creamery man would therefore pay for more fat than he actually received.

The following table gives the percentages of fat found in samples of milk, in the liquid part of the milk after it was partly frozen, and in the ice:

PERCENTAGE OF FAT FOUND IN MILK IN VARIOUS CONDITIONS AS TO FREEZING

Sample	Percentage of Fat		
	In Original Milk	In Partly Frozen Milk	
		Liquid Part	Ice
1	2.9	3.1	2.6
2	3.9	4.2	3.2
3	4.7	5.0	3.7
4	1.8	1.9	1.6
5	2.3	2.5	2.2
6	4.7	5.0	4.1
7	3.7	4.4	3.0
8	3.2	3.5	3.3
9	3.6	3.8	3.2
10	4.2	4.3	3.9

TESTING SOUR MILK (Ross)

Sour milk should not be tested unless such testiug is absolutely necessary. It is difficult to test sour milk because the casein has been precipitated and the fat is locked up in the particles of curd, making an even distribution of the fat impossible. The consistency of sour milk can be made more like that of normal milk by the addition of strong alkali, which drives, or tends to drive, the casein into suspension. The particles of fat are then released. Caustic soda and caustic potash are useful in restoring the consistency of sour milk, and it is best to add them in the dry form because, when so used, they do not dilute the milk to any appreciable extent and it is *unnecessary to make any correction when reading the fat column.* If a liquid alkali is used, the milk is diluted and a corresponding correction must be made when the fat column is read.

TESTING CHURNED MILK (Ross)[1]

Churned milk should not be tested if it can be avoided. When it is absolutely necessary to test churned milk, the milk should be heated to about 85° F. and well shaken, and the sample should be drawn quickly. If the sample is badly churned, euough ether should be added to dissolve the fat. After *thoroughly mixing, the sample is drawn, the ether is* evaporated, and the quantity of ether takeu is weighed. The sample is then tested in the usual manner, a correction in the reading being made for the quautity of ether nsed.

ACIDITY OF MILK[2] (Ross)

The acidity of milk is of two kinds — apparent and real acidity. The apparent acidity is due to the acid reaction of

[1] C. U. Bul. 337.
[2] A Dairy Laboratory Guide, Orange Judd Co.

the acid phosphates and casein. The real acidity is due to the presence of lactic acid ($C_3H_6O_3$), which is produced by the action of bacteria upon the sugar of the milk. The following reaction is supposed to be the one which takes place:

$$C_{12}H_{22}O_{11} + H_2O = 4C_3H_6O_3$$

The apparent acidity, according to Van Slyke, does not go above .08 per cent to .1 per cent, and is of minor importance so far as dairy work is concerned. In determining the acidity of milk it is assumed that all of the acidity is due to the presence of lactic acid.

The real acidity will ordinarily go as high as 1 per cent and in some cases higher. Usually, however, when from .8 per cent to 1 per cent acidity is reached, the lactic acid organisms will cease working. If a part of the acid is nentralized, the organisms will again commence the production of acid.

Lactic acid is important in the manufacture of dairy products. For example, butter is churned from cream which is soured or "ripened" by lactic acid. The presence and amount of lactic acid is very important all through the process of cheese-making. In many cases the nature of the product depends on the amount of acid present dnring the successive steps of manufacture.

For these reasons it is necessary to have some means of finding the amount of acid in the milk. The process by which this is done is called titration. It is a principle of chemistry that an alkali will neutralize an acid. In order, therefore, to find the acid in the milk, we take a known quantity of the milk and measure into it an alkali whose strength we know. The instrument used to measure the amount of alkali used is called a burette, and the unit of measure is the cubic centimeter. It is commonly graduated as fine as tenths of a cubic centimeter. One can tell when all of the acid is neutralized by means of an indicator. The indicator used most in dairy work is phenolphthalein, which is colorless in acid and pink in alkali. If two or

three drops of the indicator are put in milk, the color will not change, because the milk is acid in reaction. The instant that just enough alkali is added to the milk to neutralize all of the acid, the solution will turn pink.

It is a chemical fact that equal volumes of acids and alkalies of the same chemical strength will exactly neutralize one another. In 1 c.c. of a normal solution of lactic acid there are .09 gram of lactic acid. According to the above rule 1 c.c. of any normal alkali solution would just neutralize .09 gram of lactic acid.

In actual practice a solution weaker than a normal solution is usually employed, because a normal solution is so strong that any small variation in the amount used makes a big variation in results. A common solution used is 1/10 normal (expressed $n/10$). One c.c. of an $n/10$ alkali solution would neutralize .009 gram of lactic acid. An example will illustrate how the percentage of acid in milk is calculated. Suppose it took 6 c.c. of $n/10$ alkali solution to neutralize the acid in 20 grams of milk. What is the per cent of acid? One c.c. of $n/10$ alkali will neutralize .009 gram of lactic acid. Six c.c. will neutralize $6 \times .009 = .054$ gram of acid. $.054 \div 20 = .0027$. $.0027 \times 100 = .27$ per cent acid in the milk. Formulated, the above example is expressed as follows:

$$\frac{.009 \times 6}{20} \times 100 = .27 \text{ per cent.}$$

If the milk for the acid test is measured in cubic centimeters, it should be reduced to grams by multiplying by the specific gravity of milk. The acid is obtained in terms of grams, and we cannot divide grams by cubic centimeters and obtain per cent.

Farrington has devised some alkali tablets, each one of which will neutralize .03492 gram of lactic acid. These tablets are dissolved in water and an alkali solution made.

The strength of the solution will vary according to the number of tablets used and the number of cubic centimeters of water in which they are dissolved. The indicator is added to the tablets when they are manufactured. Consequently, when using an alkali tablet solution no phenolphthalein is needed. A concrete example will show how these tablets are used.

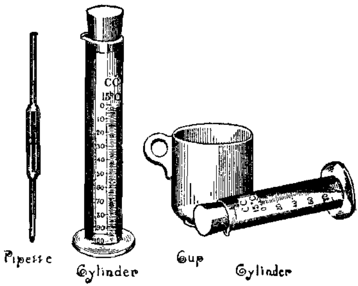


FIG. 36. — Apparatus for the Farrington acid test.

Suppose that it required 15 c.c. of an alkali tablet solution to neutralize the acid in 20 grams of milk. The tablet solution was made by dissolving five tablets in 100 c.c. of water. What is the per cent of acid in the milk? .03492 = gram of lactic acid one tablet will neutralize. .03492 × 5 = .1746 gram of lactic acid five tablets will neutralize. Since the five tablets are dissolved in 100 c.c. of water, .1746 is the amount of lactic acid 100 c.c. of the solution will neutalize. Then .1746 ÷ 100 = .001746, the strength of 1 c.c. of the solution; in other words, the number of grams of lactic acid 1 c.c. of the solution will neutralize.

$$.001746 \times 15 = .026190$$
$$.026190 \div 20 = .0013095 \times 100 = .13095 \text{ per cent}$$

If five of the alkali tablets are dissolved in 97 c.c. of water, each cubic centimeter of the solution will neutralize .01 per cent of acid when 18 grams of milk are used. This solution is often

used by creamery men, as the percentage of acid may then be read directly from the burette. Many devices for testing the acidity of milk are on the market, all tending to do away with computation and giving the percentage of acid directly. One of these is Publow's acidimeter (see p. 300). In this apparatus an $n/10$ alkali solution is used and 9 grams of milk are tested. Each cubic centimeter on the burette equals .1 per cent acid and each 1/10 of a cubic centimeter equals .01 per cent acid. In testing for acid one should always try to obtain the same degree of color each time. This color should be permanent for at least one minute. Great care should be taken not to run in an excess of alkali. It will be much easier to detect the color change if some water is added to the sample after it is measured out before the alkali is added.

TESTS FOR SOLIDS NOT FAT AND TOTAL SOLIDS IN MILK (Ross) [1]

The instrument used to measure the specific gravity of a liquid is called a hydrometer, and there are many kinds of specialized hydrometers. The hydrometer used to test the density of milk is called a lactometer, and, for the most part, only two kinds are used. One is the Quevenne (called Q. for abbreviation) and the other is called the Ordinary, or New York State Board of Health (commonly called the "B. of H." lactometer).

The Quevenne lactometer has a long, narrow stem which is extended into a hollow glass tube of much larger diameter than the stem itself. At the lower end of the instrument is a bulb of mercury which causes the lactometer to sink in the liquid to its proper level. The upper part of the stem contains a thermometer scale, as it is important to know the temperature of the milk when the lactometer reading is taken. This scale does not record high temperature, and, therefore, the

[1] A Dairy Laboratory Guide, Orange Judd Co.

instrument should never be placed in hot liquids. In order to clean the lactometer, wash in cool water and wipe with a dry cloth. Immediately below the thermometer scale is a lactometer scale with numbers ranging from 15 to 45, the lowest readings being at the upper end of the scale. One may obtain the specific gravity reading by prefixing 1.0 before the lactometer reading. Thus, if the instrument gives a reading of 33, the specific gravity would be 1.033. The fact that the Quevenne lactometer gives specific gravity readings directly is one of its chief advantages.

Temperature affects the density of liquids. The colder the milk the more dense it is, and the warmer the milk the less dense it is. For this reason lactometers are standardized to give readings at a temperature of 60° F. When milk is warmer or colder than 60° F., a correction must be made, and this correction for the Quevenne is .1 of a lactometer degree for every degree in temperature that the sample is above or below the standard temperature. When we cool the milk down, we add; when we warm the milk, we subtract. For example, if a lactometer gave a reading of 32 at a temperature of 66° F., we would add .6 (.1 × 6) to the *lactometer reading, making the corrected* or true reading 32.6. In this case the specific gravity would be 1.0326.

The Board of Health lactometer is an instrument giving arbitrary readings and must be changed to equivalent Quevenne readings in order to obtain the specific gravity. It is of the same general shape as the Quevenne, except that the thermometer scale is usually on the opposite side of the stem from the lactometer scale. The instrument is graduated from 0 to 120, and one degree Board of Health equals .29 of one degree Quevenne. In order, therefore, to change from Board of Health to Quevenne, the Board of Health reading is multiplied by .29. Vice versa, to change from Quevenne to Board of Health reading, the Quevenne reading is divided by .29. Like the Quevenne,

the Board of Health lactometer is graduated to be read at a temperature of 60° F., and if the temperature is above or below the standard, the correction factor is .3 of one lactometer degree for every degree that the sample is above or below the standard. The following example will illustrate how correction is made: B. of H. reading 110.5 at 65° F., what would be the reading at 60° F.? The sample must be cooled down 5 degrees; therefore, we would add 1.5 (5 × .3) to the reading (110.5), making a corrected reading of 112.0. One of the chief advantages of the B. of H. lactometer is that a small adulteration of the milk will make a noticeable change in the lactometer reading. This is because the instrument has so large a scale. Also, when milk is watered, the number of lactometer degrees recorded below 100 indicates roughly the percentage of adulteration.

When used in connection with the Babcock test, the lactometer reading is important in obtaining the total solids and solids not fat of milk. There are several of these formulæ in use, and while they do not give quite as accurate results as the chemical method, they give results which are accurate enough for all practical purposes. They are as follows:

1. $\frac{L + .7\,f}{3.8}$ = S. N. F. Babcock's formulæ.

2. $\frac{L + F}{4}$ = S. N. F. Troy's formulæ.

3. $\frac{1}{4}\,L + .2\,f + .14$ = S. N. F. Babcock's modified formula.

Generally speaking, the first formula gives the highest results, the second next highest, and the third the lowest results. One can find the total solids by adding the fat reading to the solids not fat. In these formulæ L stands for the lactometer reading and F for the fat reading.

In using these formulæ, the following precautions must be

especially noted: Board of health readings can never be used in these formulæ, consequently B. of H. readings must be changed to Q.; specific gravity readings cannot be used; the percentage of fat expressed in hundredths cannot be used.

An illustrative example will show how these formulæ operate. Suppose the Q. lactometer reading of a sample of milk was 32.5 at 60° F. and the fat reading was 4.2 per cent, what are the solids not fat?

Formula 1 =

$$\frac{L + .7\,f}{3.8} = S.\ N.\ F. \quad .7 \times 4.2 = 2.94$$

$$2.94 + 32.5 = 35.44$$

$$35.44 \div 3.8 = 9.32^{+}$$

Formulating the above calculation:

$$\frac{32.5 + 2.94}{3.8} = 9.32\,\%\ S.\ N.\ F.$$

$$9.32 + 4.2 = 13.52 \text{ total solids}$$

Using formula 2:

$$\frac{L + F}{4} = S.\ N.\ F.$$

$$32.5 + 4.2 = 36.7$$

$$36.7 \div 4 = 9.17^{+}\,\%\ S.\ N.\ F.$$

Formulating the above calculation:

$$\frac{32.5 + 4.2}{4} = 9.17\ S.\ N.\ F.$$

$$9.17 + 4.2 = 13.37\ T.\ S.$$

Using formula 3:

$\frac{1}{4}$ L + .2 f + .14 = S. N. F.

32.5 ÷ 4 = 8.12

.2 × 4.2 = .84

8.12 + .84 + .14 = 9.10 S. N. F.

9.10 + 4.2 = 13.30 T. S.

By modifying Babcock's third formula the total solids may be obtained directly. It is as follows:

$\frac{1}{4}$ L + 1.2 f + .14 = T. S.

Using the above lactometer and fat readings as an illustration, the formula would give the following results:

32.5 ÷ 4 = 8.12

1.2 × 4.2 = 5.04

8.12 + 5.04 + .14 = 13.30% T. S.

Table for Determining Total Solids in Milk from Any Given Specific Gravity and Percentage of Fat

Percentage of Fat	Lactometer Reading at 60° F. (Quevenne Degrees)										
	26	27	28	29	30	31	32	33	34	35	36
	per cent total solids	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*
2.00	8.90	9.15	9.40	9.65	9.90	10.15	10.40	10.66	10.91	11.16	11.41
2.05	8.96	9.21	9.46	9.71	9.96	10.21	10.46	10.72	10.97	11.22	11.47
2.10	9.02	9.27	9.52	9.77	10.02	10.27	10.52	10.78	11.03	11.28	11.53
2.15	9.08	9.33	9.58	9.83	10.08	10.33	10.58	10.84	11.09	11.34	11.59
2.20	9.14	9.39	9.64	9.89	10.14	10.39	10.64	10.90	11.15	11.40	11.65
2.25	9.20	9.45	9.70	9.95	10.20	10.45	10.70	10.96	11.21	11.46	11.71
2.30	9.26	9.51	9.76	10.01	10.26	10.51	10.76	11.02	11.27	11.52	11.77
2.35	9.32	9.57	9.82	10.07	10.32	10.57	10.82	11.08	11.33	11.58	11.83
2.40	9.38	9.63	9.88	10.13	10.38	10.63	10.88	11.14	11.39	11.64	11.89
2.45	9.44	9.69	9.94	10.19	10.44	10.69	10.94	11.20	11.45	11.70	11.95
2.50	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.26	11.51	11.76	12.01
2.55	9.56	9.81	10.06	10.31	10.56	10.81	11.06	11.32	11.57	11.82	12.07
2.60	9.62	9.87	10.12	10.37	10.62	10.87	11.12	11.38	11.63	11.88	12.13
2.65	9.68	9.93	10.18	10.43	10.68	10.93	11.18	11.44	11.69	11.94	12.19
2.70	9.74	9.99	10.24	10.49	10.74	10.99	11.24	11.50	11.75	12.00	12.25
2.75	9.80	10.05	10.30	10.55	10.80	11.05	11.31	11.56	11.81	12.06	12.31
2.80	9.86	10.11	10.36	10.61	10.86	11.11	11.37	11.62	11.87	12.12	12.37
2.85	9.92	10.17	10.42	10.67	10.92	11.17	11.43	11.68	11.93	12.18	12.43
2.90	9.98	10.23	10.48	10.73	10.98	11.23	11.49	11.74	11.99	12.24	12.49
2.95	10.04	10.29	10.54	10.79	11.04	11.30	11.55	11.80	12.05	12.30	12.55
3.00	10.10	10.35	10.60	10.85	11.10	11.36	11.61	11.86	12.11	12.36	12.61
3.05	10.16	10.41	10.66	10.91	11.17	11.42	11.67	11.92	12.17	12.42	12.68
3.10	10.22	10.47	10.72	10.97	11.23	11.48	11.73	11.98	12.23	12.48	12.74
3.15	10.28	10.53	10.78	11.03	11.29	11.54	11.79	12.04	12.29	12.55	12.80
3.20	10.34	10.59	10.84	11.09	11.35	11.60	11.85	12.10	12.35	12.61	12.86
3.25	10.40	10.65	10.90	11.16	11.41	11.66	11.91	12.16	12.42	12.67	12.92
3.30	10.46	10.71	10.96	11.22	11.47	11.72	11.97	12.22	12.48	12.73	12.98
3.35	10.52	10.77	11.03	11.28	11.53	11.78	12.03	12.28	12.54	12.79	13.04
3.40	10.58	10.83	11.09	11.34	11.59	11.84	12.09	12.34	12.60	12.85	13.10
3.45	10.64	10.89	11.15	11.40	11.65	11.90	12.15	12.40	12.66	12.91	13.16
3.50	10.70	10.95	11.21	11.46	11.71	11.96	12.21	12.46	12.72	12.97	13.22
3.55	10.76	11.02	11.27	11.52	11.77	12.02	12.27	12.52	12.78	13.03	13.28
3.60	10.82	11.08	11.33	11.58	11.83	12.08	12.33	12.58	12.84	13.09	13.34
3.65	10.88	11.14	11.39	11.64	11.89	12.14	12.39	12.64	12.90	13.15	13.40
3.70	10.94	11.20	11.45	11.70	11.95	12.20	12.45	12.70	12.96	13.21	13.46
3.75	11.00	11.26	11.51	11.76	12.01	12.26	12.51	12.76	13.02	13.27	13.52
3.80	11.06	11.32	11.57	11.82	12.07	12.32	12.57	12.82	13.08	13.33	13.58
3.85	11.12	11.38	11.63	11.88	12.13	12.38	12.63	12.88	13.14	13.39	13.64
3.90	11.18	11.44	11.69	11.94	12.19	12.44	12.69	12.94	13.20	13.45	13.70
3.95	11.24	11.50	11.75	12.00	12.25	12.50	12.75	13.00	13.26	13.51	13.77
4.00	11.30	11.56	11.81	12.06	12.31	12.56	12.81	13.06	13.32	13.57	13.83
4.05	11.36	11.62	11.87	12.12	12.37	12.62	12.87	13.12	13.38	13.63	13.89
4.10	11.42	11.68	11.93	12.18	12.43	12.68	12.93	13.18	13.44	13.69	13.95
4.15	11.48	11.74	11.99	12.24	12.49	12.74	12.99	13.25	13.50	13.76	14.01
4.20	11.54	11.80	12.05	12.30	12.55	12.80	13.05	13.31	13.56	13.82	14.07
4.25	11.60	11.86	12.11	12.36	12.61	12.86	13.12	13.37	13.62	13.88	14.13
4.30	11.66	11.92	12.17	12.42	12.67	12.92	13.18	13.43	13.68	13.94	14.19
4.35	11.72	11.98	12.23	12.48	12.73	12.98	13.24	13.49	13.74	14.00	14.25
4.40	11.78	12.04	12.29	12.54	12.79	13.04	13.30	13.55	13.80	14.06	14.31
4.45	11.84	12.10	12.35	12.60	12.85	13.10	13.36	13.61	13.86	14.12	14.37

TABLE FOR DETERMINING TOTAL SOLIDS IN MILK FROM ANY GIVEN SPECIFIC GRAVITY AND PERCENTAGE OF FAT — *Continued*

PERCENTAGE OF FAT	LACTOMETER READING AT 60° F. (QUEVENNE DEGREES)										
	26	27	28	29	30	31	32	33	34	35	36
	per cent total solids	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*	*per cent total solids*
4.50	11.90	12.16	12.41	12.66	12.91	13.16	13.42	13.67	13.92	14.18	14.43
4.55	11.97	12.22	12.47	12.72	12.97	13.22	13.48	13.73	13.98	14.24	14.49
4.60	12.03	12.28	12.53	12.78	13.03	13.28	13.54	13.79	14.04	14.30	14.55
4.65	12.09	12.34	12.59	12.84	13.09	13.34	13.60	13.85	14.10	14.36	14.61
4.70	12.15	12.40	12.65	12.90	13.15	13.40	13.66	13.91	14.16	14.42	14.67
4.75	12.21	12.46	12.71	12.96	13.21	13.46	13.72	13.97	14.22	14.48	14.73
4.80	12.27	12.52	12.77	13.02	13.27	13.52	13.78	14.03	14.28	14.54	14.79
4.85	12.33	12.58	12.83	13.08	13.33	13.58	13.84	14.09	14.34	14.60	14.85
4.90	12.39	12.64	12.89	13.14	13.39	13.64	13.90	14.15	14.40	14.66	14.91
4.95	12.45	12.70	12.95	13.20	13.45	13.70	13.96	14.21	14.46	14.72	14.97
5.00	12.51	12.76	13.01	13.26	13.51	13.76	14.02	14.27	14.52	14.78	15.03
5.05	12.57	12.82	13.07	13.32	13.57	13.83	14.08	14.33	14.58	14.84	15.09
5.10	12.63	12.88	13.13	13.38	13.63	13.89	14.14	14.39	14.64	14.90	15.15
5.15	12.69	12.94	13.19	13.44	13.69	13.95	14.20	14.45	14.70	14.96	15.21
5.20	12.75	13.00	13.25	13.50	13.75	14.01	14.26	14.51	14.76	15.02	15.27
5.25	12.81	13.06	13.31	13.56	13.81	14.07	14.32	14.57	14.82	15.08	15.33
5.30	12.87	13.12	13.37	13.62	13.87	14.13	14.38	14.63	14.88	15.14	15.39
5.35	12.93	13.18	13.43	13.68	13.93	14.19	14.44	14.70	14.95	15.20	15.45
5.40	12.99	13.24	13.49	13.74	14.00	14.25	14.50	14.76	15.01	15.26	15.51
5.45	13.05	13.30	13.55	13.80	14.06	14.31	14.56	14.82	15.07	15.32	15.57
5.50	13.11	13.36	13.61	13.86	14.12	14.37	14.62	14.88	15.13	15.38	15.63
5.55	13.17	13.42	13.67	13.93	14.18	14.43	14.69	14.94	15.19	15.44	15.69
5.60	13.23	13.48	13.73	13.99	14.24	14.49	14.75	15.00	15.25	15.50	15.75
5.65	13.29	13.54	13.79	14.05	14.30	14.55	14.81	15.06	15.31	15.56	15.81
5.70	13.35	13.60	13.85	14.11	14.36	14.61	14.87	15.12	15.37	15.62	15.87
5.75	13.41	13.66	13.91	14.17	14.42	14.68	14.93	15.18	15.43	15.68	15.93
5.80	13.47	13.72	13.97	14.23	14.48	14.74	14.99	15.24	15.49	15.74	15.99
5.85	13.53	13.78	14.04	14.29	14.54	14.80	15.05	15.30	15.55	15.80	16.06
5.90	13.59	13.84	14.10	14.35	14.60	14.86	15.11	15.36	15.61	15.86	16.12
5.95	13.65	13.90	14.16	14.41	14.66	14.92	15.17	15.42	15.67	15.92	16.18
6.00	13.71	13.96	14.22	14.47	14.72	14.98	15.23	15.48	15.73	15.98	16.24
6.05	13.77	14.02	14.28	14.53	14.78	15.04	15.29	15.54	15.79	16.04	16.30
6.10	13.83	14.08	14.34	14.59	14.84	15.10	15.35	15.60	15.85	16.10	16.35
6.15	13.89	14.14	14.40	14.65	14.90	15.16	15.41	15.66	15.91	16.16	16.42
6.20	13.95	14.20	14.46	14.71	14.96	15.22	15.47	15.72	15.97	16.22	16.48
6.25	14.01	14.26	14.52	14.77	15.02	15.28	15.53	15.78	16.03	16.28	16.54
6.30	14.07	14.32	14.58	14.83	15.08	15.34	15.59	15.84	16.09	16.34	16.60
6.35	14.13	14.38	14.64	14.90	15.14	15.40	15.65	15.90	16.15	16.40	16.66
6.40	14.19	14.44	14.70	14.96	15.20	15.46	15.71	15.96	16.21	16.46	16.72
6.45	14.25	14.50	14.76	15.02	15.26	15.52	15.77	16.02	16.27	16.52	16.78
6.50	14.31	14.56	14.82	15.08	15.32	15.58	15.83	16.08	16.33	16.58	16.84
6.55	14.37	14.62	14.88	15.14	15.38	15.64	15.89	16.14	16.39	16.64	16.90
6.60	14.43	14.68	14.94	15.20	15.44	15.70	15.95	16.20	16.45	16.70	16.96
6.65	14.49	14.74	15.00	15.26	15.50	15.76	16.01	16.26	16.51	16.76	17.02
6.70	14.55	14.80	15.06	15.32	15.56	15.82	16.07	16.32	16.57	16.82	17.08
6.75	14.61	14.86	15.12	15.38	15.62	15.88	16.13	16.38	16.63	16.88	17.14
6.80	14.67	14.92	15.18	15.44	15.68	15.94	16.19	16.44	16.69	16.94	17.20
6.85	14.73	14.98	15.24	15.50	15.74	16.00	16.25	16.50	16.75	17.00	17.26
6.90	14.79	15.04	15.30	15.56	15.80	16.06	16.31	16.56	16.81	17.06	17.32
6.95	14.85	15.10	16.30	15.62	15.86	16.12	16.37	16.62	16.87	17.12	17.38

PROPORTIONAL PARTS

LACTOMETER FRACTION	FRACTION TO BE ADDED TO TOTAL SOLIDS	LACTOMETER FRACTION	FRACTION TO BE ADDED TO TOTAL SOLIDS	LACTOMETER FRACTION	FRACTION TO BE ADDED TO TOTAL SOLIDS
0.1	0.03	0.4	0.10	0.7	0.18
.2	.05	.5	.13	.8	.20
.3	.08	.6	.15	.9	.23

METHODS OF DETERMINING VISCOSITY OR CONSISTENCY
(Babcock and Russell) (Fig. 37)

In order to study the relative consistency of milk products, it is necessary to have some measure that will indicate slight differences in the substances considered. For this purpose different viscometers have been employed, such as noting the time required for a given volume of liquid to be discharged through an opening of standard size, as in a selected pipette.

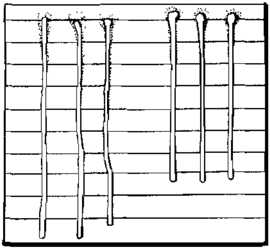


FIG. 37.—Viscometer for determining the consistency of cream.

A more sensitive method is based on measuring the resistance to a moving body immersed in a liquid. On this principle several viscometers have been devised, but for our purpose a more simple method of comparing different samples is to be desired. The following arrangement fulfills this purpose.

The necessary apparatus consists of a piece of glass (preferably plate or picture glass) about 12–15 inches square, and a pipette with a small opening which enables one to obtain

drops of uniform size. In lieu of a pipette a blunt glass rod or a floating thermometer may be used. Before using, the glass plate should be thoroughly cleaned and dried, as the smallest trace of grease or dirt materially interferes with the accuracy of the results. Ether or alcohol will facilitate the removal of the thin film of grease usually found on glass. The glass should be laid upon a flat table and then by means of the pipette or rod, drops of cream from each sample should be transferred to near one edge of the glass plate. Care should be taken that the drop falls but a little distance so that it will not spread out over too wide a surface. The drops should be placed at least one inch apart. The glass plate should then be inclined at an angle sufficient to cause all of the cream drops to flow slowly down the plate. Creams having the heavier body move more slowly, owing to the greater adhesion of the more viscous fluid to the glass. In order to eliminate any differences arising from slight variations in the surface of the glass or failure to thoroughly remove all dirt, it is better to take a number of drops from each of the creams compared, the aggregate length of the several cream paths then being taken as a measure of the relative consistency, as seen in Fig. 37.

MILK SEDIMENT TEST (Adapted from Wisconsin Circular 41)

The amount of sediment found in milk is one indication of its sanitary quality. Dirt in milk is not only unsightly but is also undesirable because of the bacteria which may be carried into the milk with it. Dirty milk usually contains large numbers of bacteria, some of which may produce very undesirable flavors in the milk or the butter or cheese made from it. It is, therefore, frequently desirable to test milk for the amount of sediment or insoluble dirt which it contains.

The sediment test is made by straining a pint, or about a pound, of milk through a cotton disk one inch in diameter,

which is attached to the bottom of the tester. A handy type of tester is shown in Fig. 38. The amount of dirt that collects on the disk shows the amount of dirt contained in that pint of milk. *The disk is readily replaced by a new one and* thus many samples of milk can be successively tested. The rapidity with which the milk is filtered through the cotton is quite important where a large number of samples are to be tested; this filtration may be hastened by applying either heat or pressure to the milk. One type of these testers is provided with a steam jacket for heating the milk; and another, with a tightly closed cover and a rubber pressure bulb by means of which the milk is forced through the filter. No heat is necessary with the latter. After one sample of milk has passed through the filter this is removed and placed on a small card or piece of white paper. A new cotton disk is then placed on the wire gauze of the apparatus and another sample tested.

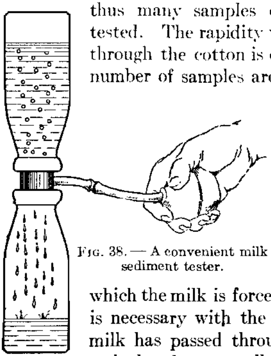


FIG. 38. — A convenient milk sediment tester.

Test for the detection of formaldehyde.

Five c.c. of milk are measured into a white porcelain dish, and a similar quantity of water added; 10 c.c. of hydrochloric acid (HCl), containing a trace of tetrachloride of iron (Fe_2Cl_6), is added, and the mixture is heated very slowly. If formaldehyde is present, a violet color will be formed. (Testing Milk and Its Products, Farrington and Woll, p. 249.)

Test for boracic acid (borax, borates, preservaline, etc.).

One hundred c.c. of milk are made alkaline with a soda or potash solution, and then evaporated to dryness and incinerated. The ash is dissolved in water, to which a little hydrochloric

acid has been added, and the solution filtered. A strip of turmeric paper moistened with the filtrate will be colored reddish brown when dried at 100° C. on a watch glass, if boracic acid is present.

If a little alcohol is poured over the ash to which concentrated sulfuric acid has been added, and fire is set to the alcohol, after a little while this will burn with a yellowish green tint, especially noticeable if the ash is stirred with a glass rod and when the flame is about to go out. (Testing Milk and Its Products, Farrington and Woll, p. 247.)

Test for salicylic acid (salicylates, etc.).

Twenty c.c. of milk are acidulated with sulfuric acid and shaken with ether; the ether solution is evaporated, and the residue treated with alcohol and a little iron-chloride solution; a deep violet color will be obtained in the presence of salicylic acid. (Testing Milk and Its Products, Farrington and Woll, p. 248.)

Test for benzoic acid.

Two hundred and fifty to 500 c.c. of milk are made alkaline with a few drops of lime or baryta water, and then evaporated to about a quarter of the bulk. Powdered gypsum is stirred into the remaining liquid until a paste is formed, which is then dried on the water bath. The gypsum only serves to hasten the drying, and powdered pumice stone or sand can be used equally well. When the mass is dry, it is finely powdered and moistened with dilute sulfuric acid and shaken out three or four times with about twice the volume of 50 per cent alcohol, in which benzoic acid is easily soluble in the cold, the fat only being dissolved to a very slight extent or not at all. The acid alcoholic liquid from the various extractions, which contains milk-sugar and inorganic salts in addition to the benzoic acid, is neutralized with baryta water and evaporated to a small bulk. Dilute sulfuric acid is again added, and the liquid shaken out with small quantities of ether. On evapora-

tion of the ether, the benzoic acid is left behind in almost pure state, the only impurities being small quantities of fat or ash.

The benzoic acid which is obtained is dissolved in a small quantity of warm water, a drop of sodium acetate and neutral ferric chloride added, and the red precipitate of benzoate of iron indicates the presence of the acid. (Milk and Dairy Products, Barthel; translated by Goodwin, p. 121.)

Detection of heated milk — Storch's method.

Five c.c. of milk are poured into a test tube; a drop of weak solution of hydrogen dioxide (about 0.2 per cent), which contains about 0.1 per cent sulfuric acid, is added, and two drops of a 2 per cent solution of paraphenylendiamin (solution should be renewed quite often), then the fluid is shaken. If the milk or the cream becomes, at once, indigo blue, or the whey violet or reddish brown, then this has not been heated or, at all events, it has not been heated higher than 78° C. (172.5° F.); if the milk becomes a light bluish gray immediately or in the course of half a minute, then it has been heated to 79° to 80° C. (174.2° to 176° F.). If the color remains white, the milk has been heated at least to 80° C. (176° F.). In the examination of sour milk or sour buttermilk, limewater must be added, as the color reaction is not shown in acid solution.

Arnold's guaiac method.

A little milk is poured into a test tube and a little tincture of guaiac is added, drop by drop. If the milk has not been heated to 80° C. (176° F.), a blue zone is formed between the two fluids; heated milk gives no reaction, but remains white. The guaiac tincture should not be used perfectly fresh, but should have stood a few days and its potency have been determined. Thereafter it can be used indefinitely. These tests for heated milk are only active in the case of milks which have been heated to 176° F. or 80° C. (Jensen's Milk Hygiene, Pearson's translation, p. 192.)

Microscopic test for heated (pasteurized) milk. (Frost and Ravenel.)

About 15 c.c. of milk are centrifuged for five minutes, or long enough to throw down the leucocytes. The cream layer is then completely removed with absorbent cotton and the milk drawn off with a pipette, or a fine-pointed tube attached to a Chapman air pump. Only about 2 mm. of milk are left above the sediment which is in the bottom of the sedimentation tube.

The stain, which is an aqueous solution of safranin 0, soluble in water, is then added very slowly from an opsonizing pipette. The important thing is to mix stain and milk so slowly that clotting does not take place. The stain is added until a deep opaque rose color is obtained. After standing three minutes, by means of the opsonizing pipette, which has been washed out in hot water, the stained sediment is then transferred to slides. A small drop is placed at the end of each of several slides and spread by means of a glass spreader, as in Wright's method for opsonic index determinations.

In an unheated milk the polymorphonuclear leucocytes have their protoplasm slightly tinged or are unstained.

In heated milk the polymorphonuclear leucocytes have their nuclei stained. In milk heated to 63° C. or above, practically all of the leucocytes have their nuclei definitely stained. When milk is heated at a lower temperature, the nuclei are not all stained above 60° C. The larger number, however, are stained.

CHAPTER VI

MARKET MILK

The production of milk for direct consumption is one of the important branches of the dairy industry, and becomes increasingly so with the continued rapid growth of the cities. The ideal milk supply is the one which reaches the consumer in the condition in which it leaves the udder of the healthy cow. Where milk is consumed at the place of production, such a supply is possible because the conditions of production are known and the milk is consumed while fresh, but in the case of the general milk business, such a supply is impossible, for the consumer has no control over the conditions of production and does not receive the milk until it is many hours old. Several things are important in the quality of milk and cream for direct consumption.

1. Chemical composition.
2. Freedom from disease-producing microörganisms.
3. Freedom from bacterial decomposition products.
4. Cleanliness, including both dirt and bacteria.

The nutritive value of milk depends primarily on the amount of fat and solids it contains. (See Fig. 39.) Since the relation between the fat and the other solids is fairly constant, and since the total solids vary almost directly with the percentage of fat, the nutritive value of milk and cream is usually considered to be in proportion to the percentage of fat contained. If the percentage of fat is abnormally high or low, the normal ratio of fat to other solids will be out of balance, but within normal

limits the food value increases with the fat-content. Some persons cannot readily digest large amounts of fat and, for such persons, milk low in fat may be desirable, and in some cases milk from which the fat has all been removed may be preferable.

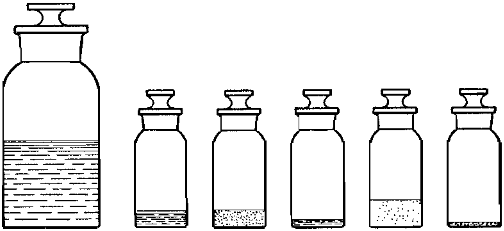


FIG. 39. — The constituents of a quart of milk.

Water	Fat	Casein	Albumin	Sugar	Ash
87 %	4 %	2.6 %	.7 %	5 %	.7 %
29.93 oz.	1.38 oz.	.89 oz.	.24 oz.	1.72	24 oz.

From the standpoint of wholesomeness, it is of the greatest importance that the milk shall be free from disease-producing microörganisms. Therefore, the cows should be healthy, free from all disease, and kept in good sanitary conditions and supplied with wholesome food and pure water. Persons handling the milk must also be free from disease and have no contact with other persons who are sick.[1]

No other food will undergo fermentation as rapidly as milk. This is because milk is an ideal medium for the growth of many forms of bacteria. It contains the necessary food and moisture in the best form for the use of these organisms and, if the proper temperatures are provided, they can grow with

[1] For further discussion of this subject, see chapter on Relation of Bacteria to Dairy Products.

marvelous rapidity. The proteids and milk-sugar are most easily broken down, causing changes in chemical composition and the production of by-products which affect the commercial value of the milk. The most common change is the souring of the milk caused by the breaking down of the milk-sugar and the formation of lactic acid. Many other changes are caused by the growth of bacteria and yeasts, such as ropy or slimy milk, gassy milk, sweet curdling and a large variety of bad flavors and odors which seriously affect the value of the milk.[1]

The question of cleanliness is becoming more and more important in the production and handling of market milk. This is because it has been clearly shown that there is a definite relation between cleanliness and wholesomeness of the product. In its generally accepted meaning, milk cleanliness involves not only the presence or absence of visible dirt but also of microorganisms and the decomposition products resulting from their action.

If fresh milk contains a large number of bacteria, it indicates that the milk has become contaminated during the process of milking.[2]

If milk contains large numbers of bacteria when it reaches the consumer, either it is not fresh, has come from a diseased cow, or has otherwise been contaminated, or it has not been kept cool. Althongh such milk may contain no visible dirt, it is not bacteriologically clean and should not be sold as clean milk.

By exercising proper care, the number of bacteria which get into milk during the process of milking may be kept very low and their subsequent growth largely prevented by immediate cooling and holding at low temperatures.

[1] For a fuller discussion of this subject, see chapter on Relation of Bacteria to Dairy Products.

[2] Adapted from U. S. Bul. 602.

IMPORTANCE OF CLEAN MILK TO THE CONSUMER

The consumer is interested in clean milk primarily because no one cares to use a food which is not produced and handled under sanitary conditions. There is a more direct interest, however, because of the danger of contracting disease which may be communicated by this means. Serious epidemics of typhoid fever, septic sore throat, and other diseases have been disseminated through the milk supply. The weight of scientific evidence at the present time leads to the conclusion that tuberculosis may be transmitted from animals to human beings, particularly children, who consume raw milk containing tubercle bacilli.

Cleanliness is not an absolute safeguard against disease, but it is the greatest factor in preventing contamination. From the health standpoint there is great danger not only from the specific disease-producing bacteria previously mentioned, but from milk that contains large numbers of miscellaneous bacteria which may cause serious digestive troubles, especially in infants and invalids whose diet consists chiefly of milk. There is also the minor consideration of the loss to the consumer from milk souring or otherwise spoiling before it can be used. The cleaner the milk, the longer it will keep good and sweet.

IMPORTANCE OF CLEAN MILK TO THE PRODUCER

Clean milk not only benefits the consumer, but the milk-producer will find many ways in which he himself is benefited by producing clean milk. There are a number of items in this connection which, when considered alone, may seem unimportant, yet collectively they are of great importance. Moreover, they are not only of immediate value, but have a cumulative value reaching far into the future.

Most producers of market milk have experienced the chagrin of having a shipment of milk refused or returned because it

reached the market sour, tainted, or otherwise in poor condition. Such milk usually means a complete loss to the producer, as it costs too much to transport it back to the farm and because, depending on the market as an outlet for his milk, he has no means for utilizing small amounts at uncertain intervals. Another important consideration is the unpleasant effect upon the purchaser. Delivering sour or tainted milk usually results in losing the confidence of the dealer; or if it is delivered direct to the consumer, it means the loss of good customers. A reputation for clean milk means fewer complaints, a better class of patrons, and a steady market for the product of the dairy.

SOURCES OF MILK CONTAMINATION

Bacteria find their way into the milk from various sources. Some may come from the udder itself, where they grow in the milk cisterns and ducts. The greater number, however, come from the dust of the air, the dirt from the udder and flanks, from the milker, and from unclean utensils.

HOW TO PRODUCE CLEAN MILK

The cows and their care.

To have healthy cows is one of the first essentials of the production of clean milk. If the cows are diseased, their milk is apt to contain disease-producing bacteria, or be otherwise abnormal. When milk is secreted by the healthy mammary gland, it probably is free from bacteria, but as soon as it passes into the milk ducts and cistern of the udder it becomes contaminated with the bacteria which exist there. The amount of contamination from this source, however, is relatively unimportant, since the number of bacteria found in the healthy udder is not large, amounting to a few dozen to a few hundred to a cubic centimeter of milk. If the udder is diseased, the germ-content of the milk may be very large. Special attention

should be given to the udder in order to detect the occurrence of any form of inflammation or abnormal condition of the milk.

The external condition of the cow is a most important factor in the production of clean milk. One of the greatest sources of milk contamination is the dirt on the outside of the animal's body. It is therefore essential that extra care be given to keeping the cow free from accumulations of mud and manure.

Cows on pasture usually keep cleaner than when in the barn, but though they appear clean they may be very dusty and should be brushed before each milking period. When kept in stables they require a thorough cleaning at least once every day. It is well to clip the long hairs from the udder, flanks, and tail, in order that dirt may not cling to them. It is desirable that the bedding be clean, dry, and used in sufficieut quautities to promote the comfort of the animal, especially where the floor is of concrete.

The cow should not be groomed, bedded, or fed immediately before milking, as these operations fill the stable air with dust and bacteria. Frequent attention to the distribution of bedding is just as important as to supply a large amount of it. Often a tour through the stables the last thing at night and a few minutes' attention to the distribution of the bedding at that time will save half an hour's work of cleaning the cows in the morning. If the manure is daily removed a considerable distauce from the stable, bad odors from it will be kept from tainting the milk, and it will diminish the danger of contamination from filth-laden flies. The fly nuisance is caused by accumulations of manure in which the flies breed, and if conditions are favorable for daily removal of manure to the fields, this should be done. Flies carry bacteria and filth, and earnest efforts should be made to keep the stable free from them. If the stable and its surroundings are clean, free from accumulations of manure and other materials which attract flies, the stable can be kept fairly free of them by the use of fly poison

and traps. In addition to removing the accumulated manure from the gutter every day, the soiled bedding from under the cow should be raked back into the gutter and replaced with clean bedding. No animals other than cows should be allowed in the stable. The odor and flavor of milk are very readily affected by rape, cabbage, turnips, and other feeds having strong odors, and where these are used they should be given after milking, in which case there is little danger of contaminating the milk. Where pastures are overrun with garlic or wild onion, the cows should be removed from the pasture several hours before milking.

Good silage fed in reasonable amounts after milking will not injure the health of the cow nor impair the quality of the milk. It must be fed after milking and all uneaten silage removed so that the silage odors will disappear from the air before the next milking period.

Owing to the dust and odors which arise from the feeding of hay, grain, and silage, it is best, from a sanitary standpoint, to feed after milking rather than before.

The stable.

Whenever possible the stable should be on high ground with good, natural drainage. Poultry houses, privies, hog sheds, manure piles, or surroundings which pollute the stable air and furnish breeding places for flies should not be near the cow stable.

The silo may be connected with the stable by a feed room, but this room should be shut off from the stable by a tight door. This is convenient and also prevents silage odors in the stable except at feeding time. After the silage has been fed, the stable can be thoroughly aired before the next milking period.

An ideal site for a barnyard is on a south slope which drains away from the stable. If the barnyard is inclined to be muddy, it may be improved by drainage and by the use of cinders or

gravel. A clean yard is a great help in keeping the cows from becoming soiled by mud and manure.

Bank barns are generally dark and damp, as the light is often excluded from one or more sides, thus making the stable difficult to keep clean. Stables which have basements open on one side for the manure furnish a breeding place for flies. Barns which have many exposed beams, braces, and ledges on which dust may lodge are undesirable. In these old types of buildings little or no attention was paid to proper ventilation and distribution of the light. Many of them, however, can at small expense be remodeled to meet all sanitary requirements.

Construction of the barn may be less important than eareful methods in handling milk when the keeping down of the bacterial content of the milk is considered, but the barn construction may be such as to lighten the labor necessary to keep the barn and its equipment in a clean condition.

The stable should have a hard floor which can be readily cleaned; for this reason a cement floor is desirable.

The gutter back of the cows should be large enough to hold the droppings; a width of 16 to 18 inches and a depth of 7 inches are usually sufficient. The gutter should incline so as to drain readily, unless the liquid is taken up by absorbents. Types of stalls and mangers are best which present the least possible surface for collecting dust and dirt, and the least obstruction to the circulation of air. Stalls of wood have many flat surfaces and cracks which are difficult to keep clean and in case of outbreaks of disease are not easy to disiufect thoroughly. Stalls made of metal pipes are therefore preferable.

The most common defect in dairy stables is a lack of cleanliness; cobwebs on the ceiling and manure on the walls are too common in such places. The dairyman must not allow cobwebs, dust, or dirt to accumulate if he expects to produce the highest grade of milk. With a tight smooth ceiling and smooth walls without ledges, this is not difficult. Whitewash

should be freely applied at least twice a year both to walls and ceiling, as it helps to purify the stable and to keep it light. An abundance of light is necessary; 4 square feet of glass to a cow is generally sufficient if the windows are well distributed and not obstructed in any way. If the stable is located with its length north and south, it receives the purifying benefit of both the morning and afternoon sun.

Every cow stable should have a system of ventilation to keep the air fresh and pure and the cows comfortable without exposing them to injurious drafts. If the smell in the stable is disagreeable at any time, it indicates that the ventilation is deficient.

The milk-house.

The building in which the milk is handled should be convenient to the barn, but so placed as to be free from dust and stable odors. The ideal place for it is in a well-drained spot somewhat higher than the barn. It should not be near the barnyard, pig pen, privy, or other source of contamination. In cold climates it may be connected with the stable by a covered but well-ventilated passageway with self-closing doors at each end to prevent odors passing from the stable to the milk-house. With proper precautions the milk-house may be in the same building as the stable, but it should be provided with a separate entrance, and the walls between should be tight and without a communicating door or window.

The principal purpose in building a milk-house is to provide a place where dairy products may be handled apart from all other operations. To carry out this idea it is necessary to divide the interior of the building into two or more rooms in order to wash the utensils and handle the milk in separate rooms. The milk-house and all its equipment should be so planned that unnecessary steps will be avoided and labor economized to the greatest extent.

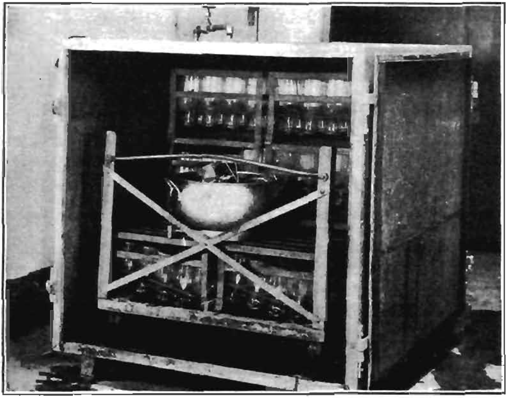
Thorough cleanliness must always be kept in mind; there-

fore there should be no unnecessary ledges or rough surfaces inside the building, so that it can be quickly and thoroughly cleaned. Milk-house floors should be of concrete and pitched to drain through bell traps. Round edges at the walls will prevent the collection of dust and dirt. The walls and ceilings may be made of matched boards, but cement plaster on painted metal lathing is better. Ventilators are necessary to keep the air in the milk room fresh and free from musty and other undesirable odors, and to carry off steam from the wash room. Windows are of prime importance, as they let in fresh air and sunlight, and facilitate work. In summer the doors and windows should be screened to keep out flies and other insects.

It is imperative that there be a plentiful supply of cold, running water at the dairy house. If it is not possible to have a gravity system, the supply may be piped from an elevated tank fed by a hydraulic ram, engine, windmill, or hand pump. The dairyman can ill afford to spend his time in carrying water in a pail to cool his milk and wash his utensils. Provision must also be made for supplying an abundance of hot water to clean and wash utensils. The water supply should be clean and abundant as well as convenient; otherwise the cleaning will not be thorough. Impure water is a source of contamination that under no circumstances should be allowed on a dairy farm. Outbreaks of typhoid fever in cities have been traced to dairy farms where the wash water was impure. Water which comes from shallow wells receiving surface drainage, or seepage from barnyard or house wastes or from pastures, is impure and should not be used.

Utensils.

All utensils which come in contact with milk should be made of durable, smooth, nonabsorbent material. Wooden utensils are hard to sterilize and therefore are not used in the best-equipped dairies. Badly battered or rusty ware is objectionable, as it is hard to clean, and contact with iron may injure



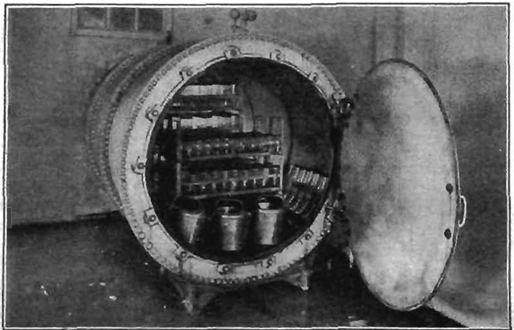


PLATE IV. — Sterilizers for dairy utensils. Above, steam without pressure. Below, steam under pressure.

the flavor of milk and milk products. Avoid all utensils having complicated parts, crevices, or inaccessible places which are hard to clean properly. (See Fig. 40.)

Milk utensils should be rinsed in cold water immediately after they have been used and before the milk has had time to dry upon them, then washed thoroughly in hot water to which soda or some washing powder has been added. Brushes are preferable to cloths for washing dairy utensils, as they are more easily kept clean and do better work.

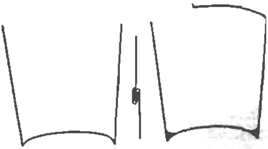


FIG. 40. — All seams and crevices should be well flushed with solder. Left and center show bad construction, right shows proper construction.

After washing, the utensils must be rinsed and sterilized. (See Plate IV.) A pail or can may be cleau to the eye and yet may carry numberless bacteria which will hasten the souring of milk, cause bad flavor in butter or cheese, or spread contagion. Disease-producing bacteria commonly found in milk are destroyed or rendered harmless on exposure to a temperature of 145° F. for twenty minutes. Some bacteria are able to withstand unfavorable conditions by passing into a resistant state known as spores, and these spores are killed only by long exposure to a temperature at or above that of boiling water.

For the proper sterilization of utensils an abundance of steam or hot water is needed. They can be immersed in boiling water for at least two minutes or held over a steam jet for the same length of time, but the most effective method is to put them into a tight closet and thoroughly sterilize with steam for at least thirty minutes. The utensils while hot should be removed from the steam or water so that they will dry quickly from their own heat, and until used should be kept inverted in a clean place, free from dust, flies, or other con-

tamination. Strainer cloths can be washed in the manner above described, boiled for five minutes, and then hung in a clean place to dry.

Milking.

Unless considerable care is taken, large numbers of bacteria may find their way into the milk during the process of milking. Cows should be milked in clean, well-lighted stables. It may be possible by taking great pains to produce good milk in a dark or dirty stable, but it is extremely improbable that clean milk will be produced under such conditions by the average person. Grooming and feeding the cattle, as well as cleaning the stable and removing the manure, should not be done just before milking, as these operations fill the air with odors, dust, and bacteria which may contaminate the milk. After grooming and before milking, the udders, flanks, and bellies of the cows should be carefully wiped with a damp cloth to remove any dust or loose hairs which might fall into the milk pail.

After the cows are prepared for milking, each milker should thoroughly wash his hands and put on a pair of clean overalls and a jumper, or wear a suit, preferably white, which is used for no other purpose. The suit must be kept clean and occasionally sterilized with steam or hot water. It is best to use a clean milking stool to avoid soiling the milker's hands.

In modern dairies where clean milk is produced the small-top milk pail is a necessity, as such a pail presents only a small opening into which dust and dirt may fall from the air or from the cow's body. It has been found by experience that the use of the small-top pail greatly reduces the number of bacteria in milk from average dairies. Many types of milk pails are for sale, but any tinner can convert an ordinary pail into a small-top pail by the addition of a hood, as shown in Plate V.

Milkers should be allowed to milk only with dry hands. The practice of wetting the hands with milk is a filthy habit and is liable to cause the cows' teats to chap in the winter time.

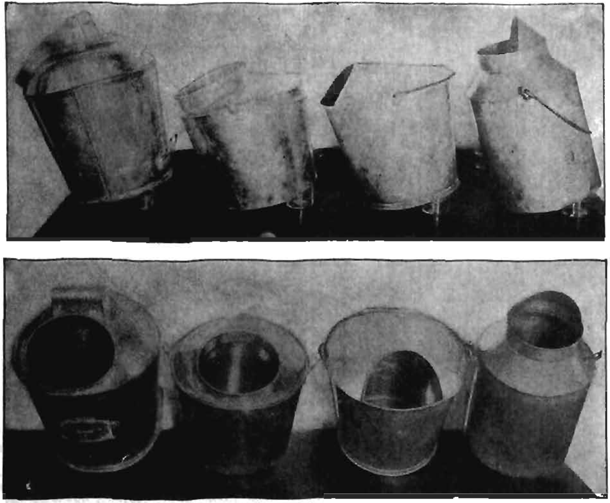


PLATE V. — Types of small top pails. The second from the right is the simplest and most practical for general use.

Milking should be done quickly and thoroughly, with no violent jerking of the teats. After each cow is milked, the pail of milk should be removed immediately to the milk house.

The milker should remember always that he is handling a human food which is very easily contaminated. Only those persons who are free from communicable disease should be allowed to handle milk or even enter the stable or dairy house.

SCORING METHODS OF PRODUCTION

In rating the sanitary conditions under which milk is produced, the score-card system has been found to be very useful, as it brings together the items which are believed to affect the sanitary quality of the milk. This is of assistance both

Equipment	Score		Methods	Score	
	Perfect	Allowed		Perfect	Allowed
COWS			COWS		
Health	6	—	Clean	8	—
Apparently in good health 1			(Free from visible dirt, 6.)		
If tested with tuberculin within a year and no tuberculosis is found, or if tested within six months and all reacting animals removed 5			STABLES		
(If tested within a year and reacting animals are found and removed, 3.)			Cleanliness of stables	6	—
Food (clean and wholesome)	1	—	Floor 2		
Water (clean and fresh)	1	—	Walls 1		
STABLES			Ceiling and ledges 1		
Location of stable	2	—	Mangers and partitions 1		
Well drained 1			Windows 1		
Free from contaminating surroundings 1			Stable air at milking time	5	—
Construction of stable	4	—	Freedom from dust 3		
Tight, sound floor and proper gutter 2			Freedom from odors 2		
Smooth, tight walls and ceiling 1			Cleanliness of bedding	1	—
Proper stall, tie, and manger 1			Barnyard	2	—
			Clean 1		
			Well drained 1		
			Removal of manure daily to 50 feet from stable	2	—
			MILK ROOM OR MILK HOUSE		
			Cleanliness of milk room	3	—

Equipment	Score: Perfect	Score: Allowed
STABLES (*Continued*)		
Provision for light: Four sq. ft. of glass per cow (Three sq. ft., 3; 2 sq. ft., 2; 1 sq. ft., 1. Deduct for uneven distribution.)	4	—
Bedding	1	—
Ventilation	7	—
Provision for fresh air, controllable flue system . . 3 (Windows hinged at bottom, 1.5; sliding windows, 1; other openings, 0.5.)		
Cubic feet of space per cow, 500 ft. . . 3 (Less than 500 ft., 2; less than 400 ft., 1; less than 300 ft., 0.)		
Provision for controlling temperature 1		
UTENSILS		
Construction and condition of utensils	1	—
Water for cleaning (Clean, convenient, and abundant.)	1	—
Small-top milking pail	5	—
Milk cooler	1	—
Clean milking suits	1	—
MILK ROOM OR MILK HOUSE		
Location: Free from contaminating surroundings	1	—
Construction of milk room	2	—
Floor, walls, and ceiling . 1		
Light, ventilation, screens . 1		
Separate rooms for washing utensils and handling milk	1	—
Facilities for steam (Hot water, 0.5.)	1	—
Total	40	—

Methods	Score: Perfect	Score: Allowed
UTENSILS AND MILKING		
Care and cleanliness of utensils	8	—
Thoroughly washed . . . 2		
Sterilized in steam for 15 minutes . . . 3 (Placed over steam jet, or scalded with boiling water, 2.)		
Protected from contamination . . . 3		
Cleanliness of milking	9	—
Clean, dry hands . . . 3		
Udders washed and wiped 6 (Udders cleaned with moist cloth, 4; cleaned with dry cloth or brush at least 15 minutes before milking, 1.)		
HANDLING THE MILK		
Cleanliness of attendants in milk room	2	—
Milk removed immediately from stable without pouring from pail	2	—
Cooled immediately after milking each cow	2	—
Cooled below 50° F. (51° to 55°, 4; 56° to 60°, 2.)	5	—
Stored below 50° F. (51° to 55°, 2; 56° to 60°, 1.)	3	—
Transportation below 50° F. (51° to 55°, 1.5; 56° to 60°, 1.) (If delivered twice a day, allow perfect score for storage and transportation.)	2	—
Total	60	—

Equipment . . . . + Methods . . . . = ... Final Score.

NOTE 1. — If any exceptionally filthy condition is found, particularly dirty utensils, the total score may be further limited.

NOTE 2. — If the water is exposed to dangerous contamination, or there is evidence of the presence of a dangerous disease in animals or attendants, the score shall be 0.

to the dairy-farmer and the milk inspector. While the score-card gives a certain value to the different factors, it must be borne in mind that our present knowledge does not make it possible to give these values with much accuracy because the relative importance of the various factors has not yet been fully established by experimental work. While it is easier to produce clean milk with good equipment, the methods used are much more important and if the necessary care is used, milk of excellent quality can be obtained even with fairly poor equipment. A number of different forms of score-cards are in use, but the preceding is the form most widely used at the present time.

TREATMENT AFTER MILKING

Straining.

The practice of straining milk to remove dirt is a universal one. Theoretically, this should not be necessary if the milk has been produced under proper sanitary conditions, but the natural conditions surrounding the process of milking make it almost impossible to be certain that some particles of foreign matter have not fallen into it. For this reason, it is desirable that milk should be carefully strained. This may be done by pouring it through one or more layers of fine cheese-cloth, linen, or wire gauze. Sometimes the milk is passed through a layer of absorbent cotton or a layer of washed fine sand. The latter are rather expensive and not so generally used. In using any form of strainer, it should be borne in mind that only the insoluble dirt can be removed, as any material which is soluble will dissolve and pass through the strainer. In practice, it has been found that the percentage of foreign matter which is removable by straining may vary all the way from 10 or 12 per cent up to 90 or more, depending on the nature of the dirt. The chief purpose of straining milk is to improve its appearance, because consumers do not like to see

particles of dirt in it. Its keeping quality is not usually improved by this operation because the bacteria which control the keeping quality are very minute and will pass freely through any strainer which will allow the passage of the fat globules (see Fig. 41).

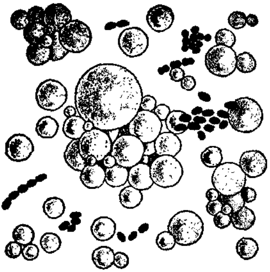


FIG. 41. — Appearance of milk under the microscope, showing relative size of fat globules and bacteria.

Aëration.

This is the process of exposing milk to the air in order to get rid of any odors which it may contain. Milk is aërated by allowing it to run over the surface of the aërator in a thin film. In this way, any foreign odors existing in the milk, in the form of gases, are allowed to escape into the air. Normal milk does not contain any odors which need to be removed, but if the cows have eaten certain strong-smelling feeds or the milk has absorbed foreign odors from the stable air, it may be desirable to aërate it. When milk is produced under proper conditions and cooled promptly, it will have no undesirable odors. This is shown by the fact that some of the highest quality milk is taken directly from the cow, bottled, and submerged in ice water with the least possible exposure to the air. The common belief that aëration improves the quality of milk is probably due to the fact that most aërators also cool the milk, and the beneficial results are due to the cooling rather than to the aëration. If an aërator is used, great care should be taken to have the atmosphere free from odors or dust. Otherwise, the final quality of the milk may be worse than the first.

Clarification of milk.

The production of milk which is entirely free from extraneous dirt requires expensive methods, and such milk cannot be sold at ordinary market prices. The increasing demand of consumers and health officers for a supply of market milk which is free from dirt and at the usual market price has led to special efforts to remove all visible dirt from ordinary milk. The ordinary centrifugal separators have been used for this purpose by passing the milk through the machine and allowing the cream and skim-milk to run into one vat where they were again thoroughly mixed; but it was soon found that this process injured the keeping quality of the milk, and the method has not come into general use in spite of the fact that this is a very efficient means of removing any foreign material from the milk. More recently a modified form of the centrifugal separator has been developed, especially for removing foreign matter from milk. These machines are known as milk clarifiers and are now in quite general use. Their efficiency is based *on the principle of centrifugal force, throwing the heavy parti*cles of dirt to the outer edge of the hollow bowl, where they are deposited as a layer of sline, together with considerable numbers of bacteria and leucocytes. This process of treating milk is very useful for the removal of dirt, but it does not improve its keeping qualities.

Cooling of milk.

In handling milk, no one factor is more important than the temperature at which it is held. Even when produced under the very best sanitary conditions, it will contain a greater or less number of bacteria, and these will multiply with astonishing rapidity if the milk is allowed to remain warm. Te prevent their rapid growth, milk should be cooled as soon as possible after it is drawn from the cow, to a temperature of 50° F. or below. The lower the temperature, the more slowly the bacteria will develop and the better will be the quality of the

milk. The effect of temperature on the growth of the bacteria and the keeping quality of the milk is shown by results obtained by dividing a lot of milk into six parts, each being held at a constant temperature for twelve hours. At the end of this time, the bacteria count was determined for each lot. The samples were then all placed at a temperature of 70° and held until they curdled.

EFFECT OF TEMPERATURE ON THE DEVELOPMENT OF BACTERIA AND THE KEEPING QUALITY OF MILK[1]

TEMPERATURE HELD FOR 12 HOURS	BACTERIA PER C.C. AT END OF 12 HOURS	HOURS TO CURDLING AT 70° F.
40° F.	4,000	75
45° F.	9,000	75
50° F.	18,000	72
55° F.	38,000	49
60° F.	453,000	43
70° F.	8,800,000	32
80° F.	55,300,000	28

The fresh milk showed a bacteria count of 5000 to a cubic centimeter, and when held at a constant temperature of 70° it curdled in fifty-two hours. It should be noted that these samples were held at the different temperatures for twelve hours only, and that the effect on the keeping quality is the result of the special temperature of this twelve-hour period, and not the entire period to the time of curdling. Prompt cooling to a low temperature is of vital importance in the handling of milk which is to be held for some hours before being consumed; and the longer the time between production and consumption, the more important this factor becomes. It must also be borne in mind that cooling does not kill the bacteria, and if the milk is allowed to warm up, they will at once become active. In order

[1] New York Dept. of Agr. Circular 10.

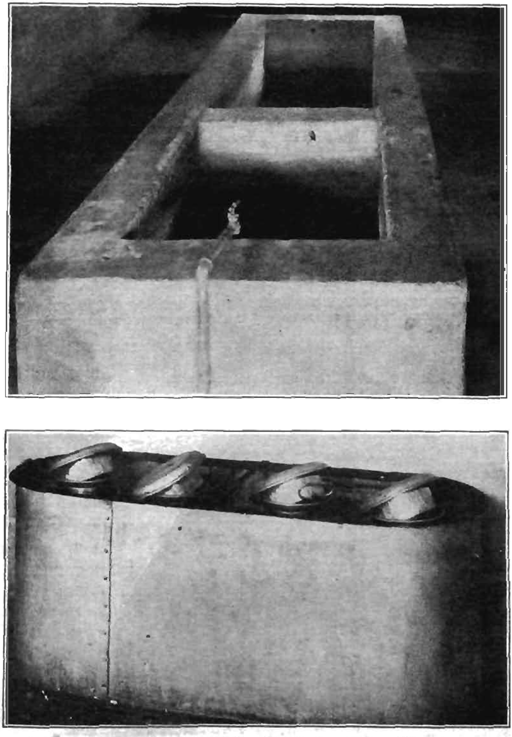


PLATE VI. — Two styles of tanks for cooling milk.

to insure the quality of the milk, the low temperature must be maintained until it is consumed.

METHODS OF COOLING MILK (Ross)

Milk becomes cool, of course, when it gives up its heat to some substance colder than itself, and in order to have a rapid exchange of temperatures between two substances it is necessary that they have approximately the same density. On account of the great difference in density between air and milk, the latter will cool very slowly in air even though the temperature of the air is rather low. If milk is allowed to cool by standing in a cold atmosphere, it will do so unevenly, and by the time the milk in the center of the can is cooled, that part near the walls of the can may be frozen. The fat is not evenly distributed in frozen milk; therefore it is not so good as normal milk.

On farms milk is most often cooled by setting the cans containing it in a tank of water. The most convenient and in the long run the cheapest kind of tank for this purpose is made of cement and sunk in the floor so that only about twelve inches of the sides extend above it. (See Plate VI.) This arrangement obviates lifting the cans to any great height and prevents dirt from washing into the tank. The top of the walls of the tank should be faced with strap iron to prevent the cans cracking the cement as they are lifted in and out. Some outlet should be provided in the bottom of the tank so that it can be easily and thoroughly cleaned as often as may be necessary. It is almost impossible to prevent milk from spilling into a cooling tank of this sort, and unless this is cleaned out, the tank soon becomes unfit for use from a sanitary standpoint. Outlets should be made at the top of the tank in order to carry off surplus water and to prevent the cans from being flooded.

Another type of cooling tank is made of galvanized iron faced

with iron at the top and the bottom. (See Plate VI.) Such a tank is not so serviceable as one made of cement, but it is more durable than a wooden one and is easier to keep clean. A galvanized iron tank large enough for cooling four or five cans of milk may be bought for eight to ten dollars.

In size the tank should be large enough to hold the required number of cans and to allow about three inches between each can and about four inches between the cans and the walls of the tank. The larger the tank, the greater is the amount of ice needed to cool the water around the cans; therefore the tank should be no larger than necessary. It must of course be deep enough to allow the water to rise around the necks of the cans.

Refrigerating material.

The refrigerating material most commonly used in cooling milk in tanks is cold water or ice water. It is generally necessary to use ice, since few wells or springs furnish water sufficiently cold to cool milk to the proper temperatures. The amount of ice necessary can best be determined by experiments, because it varies with the amount of milk to be cooled, the temperature of the surrounding atmosphere, and the temperature of the water in which the ice is placed.

Effect of stirring milk during cooling in tanks.

The cooling process, in order to be thorough, requires more than setting the can of milk in a tank of water; the milk must be stirred frequently. If the milk is not stirred, that which is near the walls of the can will become cold, while that in the center of the can will, for a long time, maintain a high temperature favorable to the growth of bacteria. This is shown by Ross and McInerney in the table on page 169.

According to this data, at the end of twenty minutes the difference in temperature due to stirring the milk varied from 3° to 17° F., and the average difference in temperature between the milk stirred and not stirred was 9.7° F. This average drop in temperature, 9.7° F., in twenty minutes, due to stirring, means

EFFECT OF STIRRING MILK ON RAPIDITY OF COOLING

Can	Stirred at Intervals of 10 Minutes — Temperature of milk (degrees Fahrenheit) at		Not Stirred — Temperature of milk (degrees Fahrenheit) at		Difference in Temperature (Degrees Fahrenheit) due to Stirring
	Beginning of experiment	End of 20 minutes	Beginning of experiment	End of 20 minutes	
1 . . .	95°	68°	95°	75°	7°
2 . . .	95°	73°	95°	85°	12°
3 . . .	90°	75°	92°	80°	5°
4 . . .	96°	73°	96°	79°	6°
5 . . .	98°	71°	98°	88°	17°
6 . . .	95°	69°	95°	78°	9°
7 . . .	98°	73°	98°	76°	3°
8 . . .	98°	73°	98°	88°	15°
9 . . .	96°	72°	98°	86°	14°
10 . . .	99°	73°	99°	82°	9°

an effective check on the development of bacteria, and a corresponding improvement in the quality of the milk. The same authors give the effect of frequency of stirring as follows:

FREQUENCY OF STIRRING ON RAPIDITY OF COOLING, WHEN CANS ARE SET IN ICE WATER, AT END OF ONE HOUR

(Adapted from Ross and McInerney)

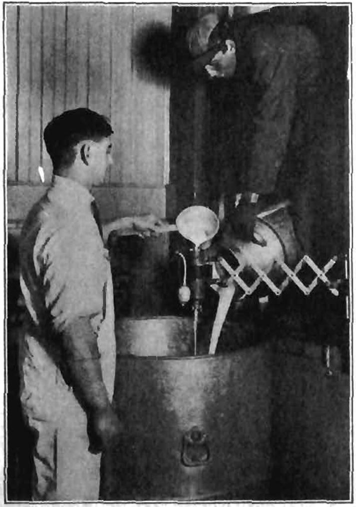
Trial No.	Not Stirred at All	Stirred every 5 Min.	Stirred every 10 Min.	Stirred Continuously
1	61°	45°	46°	39°
2	72°	54°	55°	54°
3	67°	53°	53°	47°
4	63°	57°	58°	53°
5	57°	48°	49°	41°
6	56°	52°	52°	43°
7	58°	53°	58°	44°
8	59°	55°	55°	46°
9	58°	55°	55°	46°
10	61°	54°	54°	40°
Average	61.2°	52.6°	53.5°	45.3°

For all practical purposes it seems that stirring the contents of the can once every ten minutes for an hour is sufficient.

The more quickly milk is brought to a low temperature, the more completely the growth of the bacteria will be checked and the greater will be the beneficial effect on the keeping quality of the milk. If it is desirable to cool the milk immediately after milking, it may be done by passing it over one of the various types of coolers where it comes in direct contact with a chilled surface. Plate VII shows one of the cheaper styles of coolers where the milk passes in a thin film over the outside of the drum with cold water or ice water inside. Plate VIII shows a tubular cooler which may be supplied with cold water from a storage tank or connected directly with a water system. The efficiency of this outfit will depend on the temperature of the water supply. Plate VIII shows another type of tubular cooler which may be connected with the cold water supply, or a barrel containing cracked ice and salt may be used with a small pump to force this brine mixture through the cooler. This is an inexpensive outfit by which milk may be cooled to any desired temperature above the freezing point. In using any style of milk-cooler, care should be taken to have the atmosphere free from dust and odors in order to prevent contamination of the milk during the cooling process. A milk-cooler should never be used in the cow stable, but always in a separate milk house. The efficiency of any style of cooler will depend on the temperature of the water with which the cooler is supplied.

TRANSPORTATION OF MILK (see Plates IX, X)

Where milk is peddled by the producer directly to consumers or delivered to the near-by city milk plant, the question of transportation is not a difficult one. All that is necessary is that the milk shall be well-cooled at the farm and protected from heat while on the road. Under these conditious, the



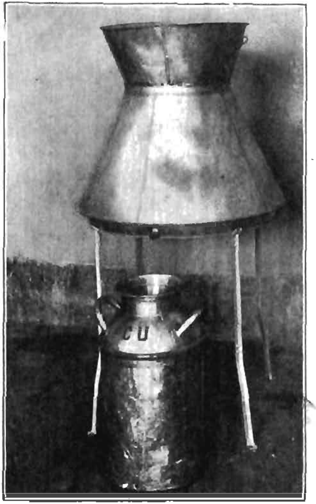


PLATE VII. — Sediment tester in operation on the weigh-stand — left. Conical milk cooler — right.

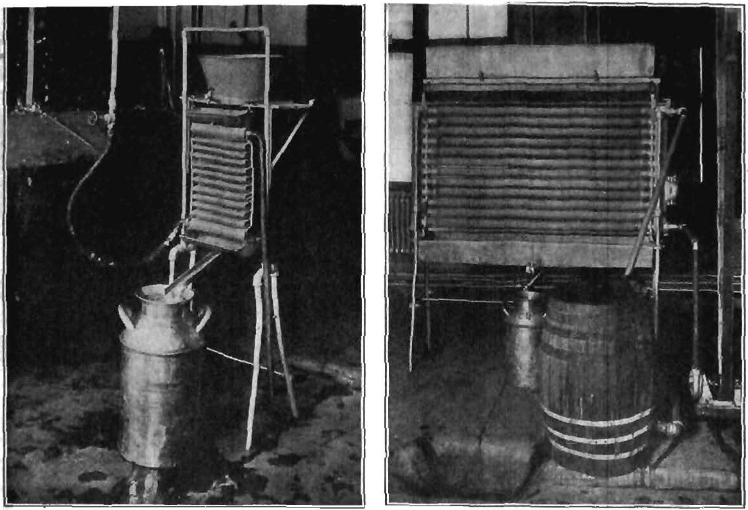


PLATE VIII. — Milk coolers. Left, attached to water system; right, operated by means of a brine barrel and pump.

length of time the milk is in transit is so short that there is little danger of its undergoing serious changes, but with the supply for the larger cities, the problem is a more serious one, because the supply must necessarily come from greater distances and be longer on the road. In the case of cities like Boston and New York, some of the supply must come from 200 to 400 miles away, which means that it must be many hours in transit before reaching the city plant. The farmer delivers the milk of the morning and previous night to the shipping station early in the morning, where it may be placed directly in the milk-car or it may first be mixed, re-cooled and re-canned, depending on the treatment given it by the farmer and the facilities provided at the plant. The milk is then picked up by the milk train and reaches the city some time during the day or following night. Under these conditions the milk coming from the more remote sections may be twenty-four or even thirty hours old on its arrival at the city plant.

Until a few years ago, milk was carried in ordinary express cars without special provision for keeping it cold, but it was found that there was a great increase in the germ-content between the time it left the country plant and its arrival in the city. Now, most of the railroad companies provide refrigerator cars designed especially for carrying milk. When these are well iced, the milk can be held at low temperatures even in the long hauls. When the proper temperatures in transit are provided, it is possible for milk coming long distances to reach the city with very little change in quality. In fact, it may be of better quality than other milk reaching the city much sooner but which was not produced under so good conditions as those received by the long haul milk.

"Milk is usually transported in heavy cans, the most common sizes holding 20, 30, or 40 quarts; the styles in use differ a good deal according to locality. Within the past few years some companies have established bottling stations near their

producing farms and transport the milk in bottles, which in hot weather are carried packed in cracked ice. This system has many advantages over the use of cans, but is more expensive. At the present time great quantities of milk are bottled by the dealers in their city plants.

"The best conducted milk companies draw their supply regularly from the same dairies, and have contracts with the farmers requiring the milk to be produced by healthy cows, strained and cooled immediately, aud sent to the city when fresh." (Farmers' Bul. 42.)

Treatment in the city.

On its arrival in the city, the milk and cream are taken to the city plant where its subsequent handling depends on its previous treatment. If it has been bottled at the country receiving plant, it may be placed immediately on the delivery wagons or put in cold storage until the wagons are ready to start. Milk which has been shipped in cans may be used for the wholesale trade or it may be bottled for retail delivery. In either case, it is held in cold storage until time of delivery. In the case of the general supply which is shipped in cans, it is strained and placed in large tanks, where it is thoroughly mixed to insure uniform quality. It may then be put through a clarifier to remove any dirt and sediment, pasteurized immediately afterwards and placed in cans or bottles as it may be needed for wholesale or retail trade. Most dealers make no effort to sell more than one grade of milk so far as chemical composition is concerned, it being simply the average composition of all the milk handled by the dealer. In the case of cream several grades may be sold ranging from about 15 per cent to 40 per cent or more of butter-fat, depending on the requirements of the trade.

PASTEURIZATION OF MILK AND CREAM (U. S. Bul. 342)

The term "pasteurization," as applied to milk, should mean a process of heating to 145° F. and holding at that temperature

Receiving platform at city terminal.

Distributing wagons loading at city terminal.

Milk cooler enclosed in glass room to prevent contamination.

PLATE IX.

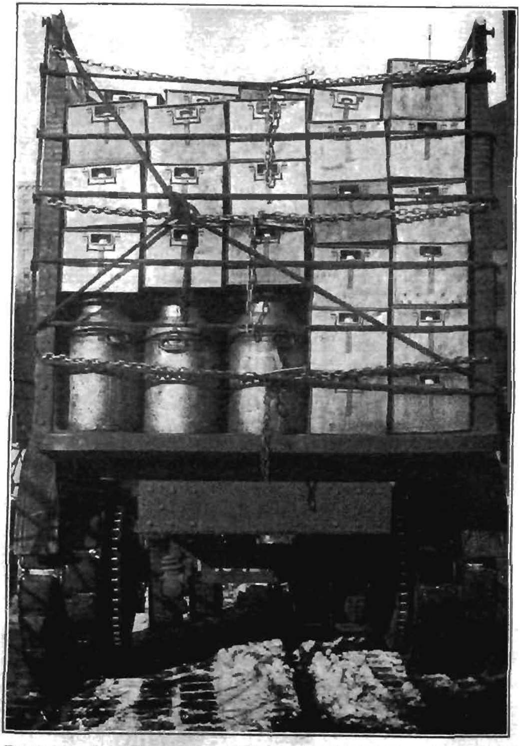


PLATE X. — Truck for hauling milk from railroad terminal to city bottling plant.

for thirty minutes, but as applied under commercial conditions it is the process of heating for a short or long period, as the different methods demand, at temperatures usually between 140° and 185° F. The process is followed by rapid cooling.

Pasteurization, when first practiced by milk-dealers in this country, was carried on secretly, and, except as a means of preserving the milk, was regarded by them as a process of no value. As the practice became more general, the subject of pasteurization was studied, and its value as a means of destroying disease-producing bacteria was recognized. In consequence of the recognition of the merits of the process there has been during the last ten years a rapid increase in the quantity of milk pasteurized, particularly in the larger cities.

The general tendency in this country to-day is toward the pasteurization of all market milk, with the exception of certified and inspected milk from tuberculin-tested herds. Some idea of the extent of pasteurization may be gained from the following table. The figures[1] were supplied by the milk-investigations section of the Dairy Division and were obtained from replies to circular letters sent to health officers.

Extent of Pasteurization of Milk in Cities in the United States

Population of Cities	Number of Cities Answering Question	More than 50 Per Cent Pasteurized	11 to 50 Per Cent Pasteurized	0 to 10 Per Cent Pasteurized	None Pasteurized
More than 500,000	9	7	2	0	0
100,001 to 500,000	40	12	20	6	2
75,001 to 100,000	19	5	8	4	2
50,001 to 75,000	30	4	15	6	5
25,001 to 50,000	78	13	31	12	22
10,001 to 25,000	168	10	40	18	100
Total	344	51	116	46	131

[1] These figures were obtained through the kindness of Mr. Ernest Kelly and Mr. L. B. Cook.

It will be seen that of nine cities with a population of more than 500,000 each, in seven more than 50 per cent of the milk is pasteurized; in fact, the proportion is much higher, as the next table shows. Since these figures were obtained the percentage of milk pasteurized has probably increased in these cities.

PROPORTION OF TOTAL MILK SUPPLY PASTEURIZED IN CERTAIN CITIES [1]

City	Per Cent Pasteurized	City	Per Cent Pasteurized
Boston, Mass.	80	Philadelphia, Pa.	85
Chicago, Ill.	80	Pittsburgh, Pa.	95
Detroit, Mich.	57	St. Louis, Mo.	70
New York, N. Y.	88		

Methods of pasteurization.

At present there are three processes of pasteurization practiced in this country. The first is known as the flash, or continuous, process; the second, the holder, or holding, process; and the third is known as pasteurization in the bottle.

The flash process consists in heating rapidly to the pasteurizing temperature, then cooling quickly. In this process the milk is heated from 30 seconds to 1 minute only, usually at a temperature of 160° F. or above.

In the holder process the milk is heated rapidly to temperatures of from 140° to 150° F. and held for approximately 30 minutes, after which it is rapidly cooled. Sometimes the milk, instead of being held at a certain temperature in one tank for 30 minutes, is merely retarded in its passage through several tanks so that the length of time is required for the milk to pass through. In such cases, however, there is no assurance that all the milk is held for the desired time. The holder process,

[1] In the small cities the per cent of milk pasteurized is much lower.

which is gradually replacing the flash process, is more effective and is superior in every way.

Pasteurization in bottles is the latest development of the process to be used on a practical scale. This process, as first practiced, consisted in putting the raw milk into bottles with water-tight seal caps, then immersing them in hot water until heated to 145° F. and holding them at that temperature for twenty or thirty minutes. The cooling was accomplished by gradually lowering the temperature of the water until that of the milk reached 50° F. This method is now in use in several milk plants. The advantage of this process is in the fact that the milk after heating is not exposed until it reaches the consumer, thereby eliminating any danger of reinfection with disease-producing organisms through handling. For this process to be successful it is necessary, of course, that the seals be absolutely water-tight, as the bottles are submerged in water, and, during cooling, a defective cap might allow infection by polluted cooling water. The disadvantage of this process is in the increased cost of pasteurization, caused by the cost of the seal caps. It is claimed, however, that the saving in milk losses by pasteurization in bottles makes up for the added expense of caps. It is now possible to pasteurize milk in this manner without using water-tight caps. This is accomplished by the aid of devices which fit over the tops and necks of the bottles, thereby protecting the ordinary paper caps from the water which is sprayed on the bottles for the purpose of heating or cooling. This method of protecting the tops permits the use of the ordinary caps and removes the possible danger of polluted water infecting the milk.

Another method of pasteurization, or, rather, a modification of the present holder process, is that of bottling hot pasteurized milk. Work on this process was begun in 1911, and the process was first suggested by the author in 1912; further work on this subject may be found in an article published

in 1914. The process consists in pasteurizing milk by the holder method at 145° F. for thirty minutes, then bottling, while hot, in hot, steamed bottles. The bottles are steamed for two minutes immediately before filling. After filling with hot milk and capping with ordinary caps the bottles may be cooled at once by any of the systems in which the caps are protected and the bottles sprayed with water, or the forced cold-air circulation may be used.

The use of forced-air circulation for cooling milk is entirely new, and while only suggested in the paper describing the process of bottling hot pasteurized milk, recent experiments with it for cooling indicate that it is practicable. We have obtained bacteriological results which show that this process is always as good as, and often superior to, the process of pasteurization in bottles. The results of these experiments are being prepared for publication. While working on this process of bottling milk hot it was found that a similar process was patented several years ago. It was described by De Schweinitz, and recently two other patents on the process have appeared.

Advantages of low-temperature pasteurization.

In general the trend of pasteurization is toward the holder process, and with this tendency the use of lower temperatures is becoming more common. As a general rule, when the holder process is used, milk is heated to 145° F. for twenty or thirty minutes and to at least 160° F. for one minute when the flash process is used. From bacteriological, chemical, and economical standpoints it is highly desirable that milk be pasteurized at low temperatures.

From a bacteriological standpoint, pasteurization at 145° F. for thirty minutes gives assnrance, so far as we know, of a complete destruction of disease-producing bacteria, and at the same time leaves in the pasteurized milk the maximum percentage of the bacteria that cause milk to sour (lactic-acid bacteria) and only a small percentage of those that cause it to

rot (peptonizers). When higher temperatures are used, while the total number of all kinds of bacteria is reduced, the percentage of lactic-acid bacteria becomes less and less and the peptonizing group increases until at 180° F., or above, when the lactic-acid bacteria are practically destroyed and the most of the bacteria left belong to the peptonizing group. The heat-resistant lactic-acid bacteria which survive pasteurization at 145° F. for 30 minutes play an important rôle in the souring of commercially pasteurized milk.

From a chemical standpoint the advantage of low temperatures is in the fact that milk pasteurized at 145° F. for thirty minutes does not undergo any appreciable change which should affect its nutritive value or digestibility. According to Rupp the soluble phosphates of lime and magnesia do not become insoluble, and the albumin does not coagulate. At 150° F. about 5 per cent of the albumin is rendered insoluble, and the amount increases with higher temperatures to 160° F., when about 30 per cent of the albumin is coagulated. The heating period in Rupp's experiment was thirty minutes.

From an economic standpoint the advantage of pasteurization at low temperatures is in the saving in the cost of heating and cooling the milk. Bowen has shown that the flash process of pasteurization requires approximately 17 per cent more heat than the holder process. There is, of course, a correspondingly wider range through which the milk must be cooled, which also adds to the cost of pasteurizing. This is owing to the fact that in the holder process milk may be heated to 145° F. and held for thirty minutes, while to obtain the same bacteriological efficiency with the flash process, with one-minute heating, the milk would have to be heated to 165° F.

Temperatures and methods most suitable for pasteurization (see Fig. 42).

In view of the advantages of low-temperature pasteurization, it is advisable to pasteurize milk at 145° F. for thirty minutes,

It has been found that heating at 140° F. for that length (time will destroy pathogenic bacteria, but in practice it is a(visable to use a temperature several degrees above the limit (

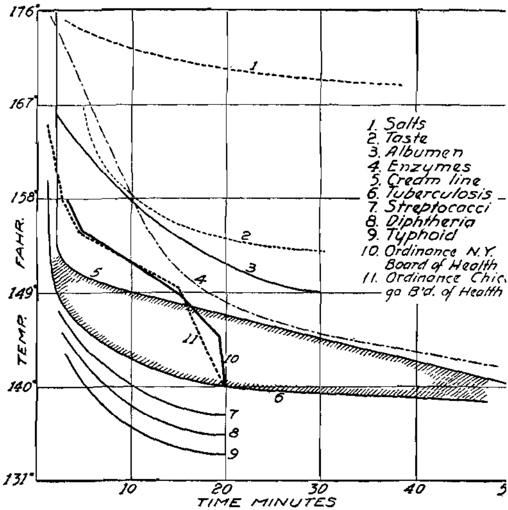


Fig. 42. — Time and temperature for milk pasteurization.

safety. During extensive studies of the effect of differen temperatures it has been shown that an increase of 5 degree above 140° F. produces a great increase in the destruction c bacteria in milk.

The holder process, as previously described, is entirel satisfactory when properly used. Considerable attention i

necessary, however, to see that the milk is not contaminated during cooling and capping.

Pasteurization in bottles eliminates the danger of reinfection, provided no water is introduced into the bottles during cooling. From a sanitary standpoint this process is very satisfactory. In the past, on account of the difficulty of treating large quantities of milk, pasteurization in bottles has not been used to any great extent in large plants.

The bottling of hot pasteurized milk in steamed bottles is a process which eliminates the danger of reinfection and can easily be adapted to the treatment of milk in large quantities.

Any one of these methods of pasteurization is satisfactory, provided a temperature of 145° F. is maintained for thirty minutes and reinfection is prevented during subsequent handling of the milk.

Handling pasteurized milk.

The pasteurization of milk destroys about 99 per cent of the bacteria; consequently the milk is not sterile. On account of this fact pasteurized milk is still a perishable product, and must be handled with the same care as raw milk. This is a point for both the consumer and the milkman to remember.

Milk after pasteurization should be cooled to about 40° F. and kept at that temperature until delivery. During warm weather it should be iced on the delivery wagons. From a sanitary standpoint all milk, whether raw or pasteurized, should be delivered as soon as possible, in order that the consumer may get it in the best condition. In the best pasteurized milk, when held at about 40° F., there is only a slight bacterial increase during the first 24 hours. In many cases the pasteurization and delivery may be so arranged that the consumer gets the milk before much, if any, change has taken place in the bacterial content. The tops of the bottles should have overlapping caps to protect them from dust, dirt, or other contamination, and the cap should be marked "Pasteurized"

and show the date and the temperature at which the milk was treated. For the benefit of the consumer this information should be printed on the cap, as it is only right for him to know whether he is using raw or pasteurized milk, and if pasteurized, the temperature may be of importance to him. Some persons object to pasteurized milk, especially for infant feeding, while others desire it. It has been the experience of numerous milk dealers that the labeling of their product has greatly increased their trade.

Cost of pasteurizing milk.

The cost of pasteurizing milk is a matter of considerable importance. It has been found by Bowen that the average cost of pasteurizing one gallon of milk is a little more than three-tenths of a cent ($0.00313). He obtained this information from a series of tests in five establishments which were considered to represent the average city milk plant. The pasteurizing equipment in each consisted of a heater, a holding tank, a regenerator, and a cooler. The cost of the operation was based on the pasteurizing cycle, starting with the initial temperature of the raw milk and raising it to the pasteurizing temperature, then cooling to the initial temperature of the raw milk. He based the costs on daily interest at 6 per cent per annum on capital invested in pasteurizing equipment, and depreciation and repairs per day at 25 per cent per annum, interest a day at 6 per cent per annum on capital invested in mechanical equipment for pasteurizing, and depreciation and repairs per day at 10 per cent per annum. Other costs figured were labor, coal at $4 a ton, cooling water at 50 cents a thousand cubic feet, and refrigeration at $1 a ton.

CONVERTING POUNDS TO QUARTS AND QUARTS TO POUNDS (Ross)

In converting quarts of milk to pounds or pounds to quarts, it is necessary to know that a quart of milk weighs 2.15 lb.

While it is true that the composition of milk is variable, the difference in weight is not great enough to affect the practicability of always using 2.15 lb. as the weight of one quart of whole milk.

The weight of a quart of cream is not constant because the percentage of fat in cream is exceedingly variable. The following table gives the weight of a quart of cream of different percentages of fat:

Percentage of Fat	Weight of One Quart of Cream in Pounds	Weight of One Gallon of Cream in Pounds
20	2.115	8.460
25	2.100	8.400
30	2.088	8.352
40	2.055	8.220
50	2.028	8.112

STANDARDIZING MILK AND CREAM (Pearson)

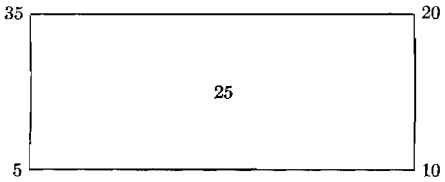
It is coming to be a more and more common practice to standardize milk and cream before sale. This means the adjustment of the fat-content to a certain desired percentage, and it is accomplished by mixing, in the proper proportion, milk and cream, or two qualities of milk or cream, one richer and one poorer than the desired standard quality. The use of skimmed milk would be prohibited for a milk mixture by the laws of some States and the ordinances of some cities. But normal milk of low enough fat-content can usually be found for all requirements.

An easy way to determine the relative amounts of the two milks or creams to be mixed is given in the following rule:

Draw a rectangle (see accompanying diagrams) and write at the two left-hand corners the percentages of fat in the two

fluids to be mixed and in the center place the standard percentage desired. Then find the difference between the number in the center and that at the upper left-hand corner, and place this at the opposite corner — the lower right-hand corner. In like manner place at the upper right-hand corner the difference between the number in the center and that at the lower left-hand corner. Now the number at the *upper right-hand* corner shows the relative number of pounds of the milk or cream whose percentage stands at the *upper left-hand* corner, which should be used in making the mixture; and the number at the *lower right-hand* corner shows the relative amount which should be used of the milk or cream whose percentage stands at the *lower left-hand* corner.

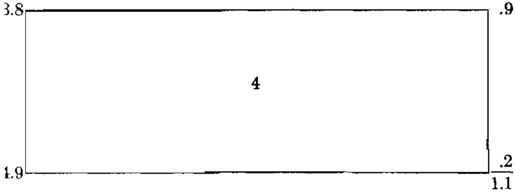
For example: Suppose we have a cream testing 35 per cent fat and a milk testing 5 per cent fat, and we want to mix them in such ratio as to produce a 25 per cent cream. Following the rule, we have this diagram:



This shows that 20 parts of the 35 per cent cream should be combined with 10 parts of the 5 per cent milk to produce 30 parts of the 25 per cent cream. In other words, the two may be combined in the ratio of 20 to 10 (or 2 to 1) to produce any desired quantity of cream testing 25 per cent fat.

Or suppose it is desired to mix milk testing 3.8 per cent fat with milk testing 4.9 per cent so as to produce 200 pounds

of milk testing 4 per cent fat. The diagram will appear as follows:



Discarding the decimal points for convenience, we can now make up the 200 pounds of 4 per cent milk by taking $\frac{9}{11}$ (or 163.64 pounds) of the amount from the milk testing 3.8 per cent and $\frac{2}{11}$ (or 36.36 pounds) from the milk testing 4.9 per cent fat.

DELIVERY IN TOWN AND CITY

There are two general methods by which milk is delivered to the consumer — by dipping from a large can into the receptacle furnished by the consumer, or in bottles which are furnished by the dealer and which are filled and capped at the milk-plant. When milk is dipped from a can, unless special care is taken to keep it well stirred, the percentage of fat in the milk delivered to different consumers may vary widely. Wing found that one customer received milk with 3.85 per cent of fat, while another served from the same can received 5.05 per cent fat. The dipping method subjects the milk to considerable exposure to dust and dirt on the street and even to infection by disease germs. This method is not approved by health officials and in most places it is going out of use. In the larger cities, dipping milk is prohibited by the health authorities, and all milk is delivered in sealed bottles. There

are many advantages in using bottles. It insures each customer getting a full quart and no more; the bottles are filled at the plant where the milk can be thoroughly mixed, insuring uniform quality, and preventing exposure to contamination from dust and microörganisms on the street.

THE COST OF CLEAN MILK [1]

There has been too much indifference on the part of consumers with respect to the cleanliness of milk; too many of them desire to buy milk at a low price and do not give any consideration to quality. Dirty milk may prove expensive as a gift, while clean milk may be economical even at a high price; the cheapest article is often the most expensive. A higher price for clean milk may be a cheap insurance against some form of sickness. It is gratifying to note, however, an increasing demand for good, clean milk. This demand has resulted in more stringent regulations concerning the sanitary conditions associated with the milk supply. Compliance with these sanitary rules requires additional care, attention, and extra expense on the part of the producer of the milk, and while this expense may not be large, it is only fair that the consumer should pay his share of the cost of improving the quality of the milk. The consumer cannot expect to purchase a clean, safe milk at the same price as a dirty milk which endangers the health of his family.

A more serious consideration is the marked increase in the cost of production which has resulted in recent years from feed and labor problems. This increase is in keeping with the increase in the cost of almost every commodity, and the consumer must expect to pay his portion of any legitimate increase in the cost of production occasioned by these conditions.

On the other hand, there is need of more attention to better

[1] Farmers' Bul. 602.

management on the average farm devoted to the production of milk. The amount of milk produced to a cow is frequently so low as to reflect seriously upon the business ability of the owner. A producer who makes no systematic effort to lower the cost of production by increasing the average production of milk per cow is entitled to little sympathy if he finds the business unprofitable. The profits yielded by a good cow often go to offset losses caused by poor cows in the same stable. The keeping of records of production of each individual in the herd, the elimination of unprofitable cows, the improvement of the herd through selection of the best producers and breeding them to a bull of dairy merit, and the selection of the best heifers from such breeding are necessary to put milk production on a sound basis. Unless the producer does these things he disregards the fundamental principles of business economy, and it is unreasonable for such a man to expect the consumer to pay him a profit on business practices which represent such economic waste. There is no good excuse for slack business methods on the dairy farm. Directions for keeping records of milk yields and cost of production are furnished by every State agricultural college and by the United States Department of Agriculture.

GRADING OF MILK AND CREAM

Until recently, but little progress was made toward separating market milk and cream into grades on the basis of sanitary or market value, but now there is a general movement in this direction, and several cities and some states have established definite grades chiefly on the basis of sanitary quality. This is in harmony with business practice in other lines, and a good system of grading will do much to insure the milk-producer being paid on the basis of the quality of his product. It will also make it possible for the consumer to purchase the grade

desired. New York City has been a pioneer in this work, and the grades established by her Board of Health will serve to illustrate this subject. They are as follows:

REGULATIONS OF THE DEPARTMENT OF HEALTH OF THE CITY OF NEW YORK RELATIVE TO THE GRADING OF MILK AND CREAM

Sec. 156. **Milk and cream; grades and designations.** — All milk or cream held, kept, offered for sale, sold, or delivered in the City of New York shall be so held, kept, offered for sale, sold or delivered in accordance with the Regulations of the Board of Health and under any of the following grades or designations and not otherwise:

"Grade A: For Infants and Children."
1. Milk or cream (raw).
2. Milk or cream (pasteurized).

"Grade B: For Adults."
1. Milk or cream (pasteurized).

"Grade C: For Cooking and Manufacturing Purposes Only."
1. Milk or cream not conforming to the requirements of any of the subdivisions of Grade A or Grade B, and which has been pasteurized according to the Regulations of the Board of Health or boiled for at least two (2) minutes.
2. Condensed skimmed milk.

The provisions of this section shall apply to milk or cream used for the purpose of producing or used in preparation of sour milk, buttermilk, homogenized milk, milk curds, sour cream, Smeteny, Kumyss, Matzoon, Zoolak, and other similar products or preparations, provided that any such product or preparation be held, kept, offered for sale, sold, or delivered in the City of New York.

REGULATIONS GOVERNING THE SALE OF GRADE "A" MILK OR CREAM (Raw)

Definition. — Grade "A" milk or cream (raw) is milk or cream produced and handled in accordance with the Regulations as herein set forth.

Regulation 113. Tuberculin test and physical condition. — Only such animals shall be admitted to the herd as are in good physical condition, as shown by a thorough physical examination accompanied by a test with the diagnostic injection of tuberculin, within a period of one month previous to such admission. The test is to be carried

out as prescribed in the Regulations of the Department of Health governing the tuberculin testing of cattle. A chart recording the result of the official test must be in the possession of the Department of Health before the admission of any animal to the herd.

Regulation 114. Bacterial contents. — Grade "A" milk (raw) shall not contain more than 60,000 bacteria per c.c. and cream more than 300,000 bacteria per c.c. when delivered to the consumer or at any time prior to such delivery.

Regulation 115. Scoring of dairies. — All dairies producing milk of this designation shall score at least 25 points on equipment and 50 points on methods, or a total score of 75 points on an official dairy score card approved by the Department of Health.

Regulation 116. Time of delivery. — Milk of this designation shall be delivered to the consumer within 36 hours after production.

Regulation 117. Bottling. — Milk or cream of this designation shall be delivered to the consumer only in bottles, unless otherwise specified in the permit.

Regulation 118. Labeling. — The caps of all bottles containing Grade "A" milk or cream (raw) shall be white, with the grade and designation "Grade A (raw)" the name and address of the dealer, and the word "Certified" when authorized by the state law, clearly, legibly, and conspicuously displayed on the outer side thereof. No other word, statement, design, mark, or device shall appear on that part of the outer cap containing the grade and the designation unless authorized and permitted by the Department of Health. A proof print or sketch of such cap, showing the size and arrangement of the lettering thereon, shall be submitted to and approved by the said Department before being attached to any bottle containing milk or cream of the said grade and designation.

ADDITIONAL REGULATIONS GOVERNING THE SALE OF GRADE "A" MILK OR CREAM (Pasteurized)

Definition. — Grade "A" milk or cream (pasteurized) is milk or cream handled and sold by dealers holding permits therefor from the Board of Health, and produced and handled in accordance with the Regulations as herein set forth.

Regulation 119. Physical examination of cows. — All cows producing milk or cream of this designation must be healthy, as determined by a physical examination made annually by a duly licensed veterinarian.

Regulation 120. Bacterial content. — Milk of this designation shall not contain more than 30,000 bacteria per c.c. and cream more than 150,000 bacteria per c.c. when delivered to the consumer or at any time after pasteurization and prior to such delivery. No milk supply averaging more than 200,000 bacteria per c.c. shall be pasteurized to be sold under this designation.

Regulation 121. Scoring of dairies. — All dairies producing milk or cream of this designation shall score at least 25 points on equipment and 43 points on methods, or a total score of 68 points on an official score card approved by the Department of Health.

Regulation 122. Times of delivery. — Milk or cream of this designation shall be delivered within 36 hours after pasteurization.

Regulation 123. Bottling. — Milk or cream of this designation shall be delivered to the consumer only in bottles unless otherwise specified.

Regulation 124. Bottles only. — The caps of all bottles containing Grade "A" milk or cream (pasteurized) shall be white with the grade and designation "Grade A (pasteurized)," the name and address of the dealer, the date and hours between which pasteurization was completed, and the place where pasteurization was performed, clearly, legibly, and conspicuously displayed on the outer side thereof. No other word, statement, design, mark, or device shall appear on that part of the outer cap containing the grade and designation, unless authorized and permitted by the Department of Health. A proof print or sketch of such cap, showing the size and arrangement of the lettering thereon, shall be submitted to and approved by the said Department before being attached to the bottles containing milk of the said grade and designation. No other words, statement, design, or device shall appear upon the outer cap unless approved by the Department of Health. The size and arrangement of lettering on such cap must be approved by the Department of Health.

Regulation 125. Pasteurization. — Only such milk or cream shall be regarded as pasteurized as has been subjected to a temperature of from 142 to 145 degrees F. for not less than thirty minutes.

ADDITIONAL REGULATIONS GOVERNING THE SALE OF GRADE "B" MILK OR CREAM (Pasteurized)

Definition. — Grade "B" milk or cream (pasteurized) is milk or cream produced and handled in accordance with the minimum requirements of the Regulations herein set forth and which has been

pasteurized in accordance with the Regulations of the Department of Health for pasteurization.

Regulation 128. Physical examination of cows. — All cows producing milk or cream of this designation must be healthy as determined by a physical examination made and approved by a duly licensed veterinarian.

Regulation 129. Bacterial contents. — No milk under this designation shall contain more than 100,000 bacteria per c.c. and no cream shall contain more than 500,000 bacteria per c.c. when delivered to the consumer, or at any time after pasteurization and prior to such delivery. No milk supply averaging more than 1,500,000 bacteria per c.c. shall be pasteurized in this city under this designation. No milk supply averaging more than 300,000 bacteria per c.c. shall be pasteurized outside the City of New York to be sold in said city under this designation.

Regulation 130. Scoring of dairies. — Dairies producing milk or cream of this designation shall score at least 20 points on equipment and 35 points on methods, or a total score of 55 points on an official score card approved by the Department of Health.

Regulation 131. Time of delivery. — Milk of this designation shall be delivered within 36 hours. Cream shall be delivered within seventy-two (72) hours after pasteurization. Cream intended for manufacturing purposes may be stored in cold storage and held thereat in bulk at a temperature not higher than 32 degrees F. for a period conforming with the laws of the state of New York. Such cream shall be delivered in containers, other than bottles, within twenty-four (24) hours after removal from cold storage and shall be used only in the manufacture of products in which cooking is required.

Regulation 132. Bottling. — Milk of this designation may be delivered in cans or bottles.

Regulation 133. — Labeling. — The caps of all bottles containing Grade " B " milk (pasteurized) and the tags attached to all cans containing Grade " B " milk or cream (pasteurized) shall be white with the grade and designation " Grade B (pasteurized)," the name and address of the dealer, and the date when and place where pasteurization was performed, clearly, legibly, and conspicuously displayed on the outer side thereof. The caps of all bottles containing Grade " B " cream (pasteurized) shall be white with the grade and designation " Grade B Cream (pasteurized)," the name and address of the dealer, and the date when and the place where bottled, clearly, legibly, and conspicuously displayed on the outer side thereof. No other word,

statement, design, mark, or device shall appear on that part of the outer cap or tag containing the grade and designation unless authorized and permitted by the Department of Health. A proof print or sketch of such cap or tag, showing the size and arrangement of the lettering thereon shall be submitted to and approved by the said Department before being attached to any receptacle containing milk or cream of the said grade and designation.

Regulation 134. Pasteurization. — Only snch milk or cream shall be regarded as pasteurized as has been subjected to a temperature of from 142 to 145 degrees F. for not less than thirty minutes.

ADDITIONAL REGULATIONS GOVERNING THE SALE OF GRADE "C" MILK OR CREAM (PASTEURIZED) (FOR COOKING AND MANUFACTURING PURPOSES ONLY)

Definition. — Grade "C" milk or cream is milk or cream not conforming to the requirements of any of the subdivisions of Grade "A" or Grade "B" and which has been pasteurized according to the Regulations of the Board of Health or boiled for at least two minutes.

Regulation 136. Physical examination of cows. — All cows producing milk or cream of this designation must be healthy, as determined by a physical examination made by a duly licensed veterinarian.

Regulation 137. Bacterial content. — No milk of this designation shall contain more than 300,000 bacteria per c.c. and no cream of this grade shall contain more than 1,500,000 bacteria per c.c. after pasteurization.

Regulation 138. Scoring of dairies. — Dairies producing milk or cream of this designation must score at least 40 points on an official score card approved by the Department of Health.

Regulation 139. Time of delivery. — Milk or cream of this designation shall be delivered within 48 hours after pasteurization.

Regulation 140. Bottling. — Milk or cream of this designation shall be delivered in cans only.

Regulation 141. Labeling. — The tags attached to all cans containing Grade "C" milk (for cooking) shall be white with the grade and designation "Grade C Milk (for cooking)," the name and address of the dealer, and the date when and place where pasteurization was performed, clearly, legibly, and conspicuously displayed thereon. No other word, statement, design, mark, or device shall appear on that part of the tag containing the grade and designation, unless authorized

and permitted by the Department of Health. A proof print or sketch of such tag, showing the size and arrangement of the lettering thereon shall be submitted to and approved by the said Department before being attached to the cans containing milk of the said grade and designation. The cans shall have properly sealed metal covers painted red.

Regulation 142. Pasteurization. — Only such milk or cream shall be regarded as pasteurized as has been subjected to a temperature of 145 degrees, for not less than thirty minutes.

ADDITIONAL REGULATIONS GOVERNING THE SALE OF CONDENSED SKIMMED MILK

Definition. — Condensed skimmed milk is condensed milk in which the butter-fat is less than twenty-five (25) per cent of the total milk solids.

Regulation 145. Cans to be painted blue. — The cans containing condensed skimmed milk shall be colored a bright blue and shall bear the words " Condensed Skimmed Milk " in block letters at least two inches high and two inches wide, with a space of at least one-half inch between any two letters. The milk shall be delivered to the person to whom sold, in can or cans, as required in this regulation, excepting when sold in hermetically sealed cans.

ADDITIONAL REGULATIONS GOVERNING THE LABELING OF MILK OR CREAM BROUGHT INTO, DELIVERED, OFFERED FOR SALE, AND SOLD IN NEW YORK CITY

Regulation 146. Labeling of milk or cream. — Each container or receptacle used for bringing milk or cream into or delivering it in the City of New York shall bear a tag or label stating, if shipped from a creamery or dairy, the location of the said creamery or dairy, the date of shipment, the name of the dealer, and the grade of the product contained therein, except as elsewhere provided for delivery of cream in bottles.

Regulation 147. Labeling of milk or cream to be pasteurized. — All milk or cream brought into the City of New York to be pasteurized shall have a tag affixed to each and every can or other receptacle indicating the place of shipment, date of shipment, and the words " to be pasteurized at (stating location of pasteurizing plants)."

Regulation 148. Mislabeling of milk or cream. — Milk or cream of one grade or designation shall not be held, kept, offered for sale, sold, or labeled as milk or cream of a higher grade or designation.

Regulation 149. Word, statement, design, mark, or device on label. — No word, statement, design, mark, or device regarding the milk or cream shall appear on any cap or tag attached to any bottle, can, or other receptacles containing milk or cream which words, statement, design, mark, or device is false or misleading in any particular.

Regulation 150. Tags to be saved. — As soon as the contents of such container or receptacle are sold, or before the said container is returned or otherwise disposed of, or leaves the possession of the dealer, the tag thereon shall be removed and kept on file in the store, where such milk or cream has been sold, for a period of two months thereafter, for inspection by the Department of Health.

Regulation 151. Record of milk or cream delivered. — Every wholesale dealer in the city of New York shall keep a record in his main office in the said city, which shall show from which place or places milk or cream, delivered by him daily to retail stores in the city of New York, has been received and to whom delivered, and the said record shall be kept for a period of two months, for inspection by the Department of Health, and shall be readily accessible to the inspectors of the said Department at all times.

UNITED STATES DEPARTMENT OF AGRICULTURE

Bureau of Animal Industry

DAIRY DIVISION

SANITARY INSPECTION OF CITY MILK PLANTS

Score Card

Owner or manager..

Street and No..

City.........................State.........................

Trade name...

Number of wagons...........Gallons sold daily {Milk............ / Cream..........}

Permit or License No............

Date of inspection................................., 191

Remarks:...

EQUIPMENT	SCORE Perfect	SCORE Allowed
BUILDING:		
Location: Free from contaminating surroundings	2	—
Arrangement	7	—
Separate receiving room . 1		
Separate handling room . 2		
Separate wash room . 1		
Separate sales room . 1		
Separate boiler room . 1		
Separate refrigerator room 1		
Construction	12	—
Floors tight, sound, cleanable . 2		
Walls tight, smooth, cleanable . 1		
Ceilings smooth, tight, cleanable . 1		
Drainage . 2		
Floors . 1		
Sewer or septic tank 1		
Provision for light . 2 (10 per cent of floor space)		
Provision for pure air . 2		
Screens . 1		
Minimum of shafting, pulleys, hangers, exposed pipes, etc. . 1		
APPARATUS	15	—
Boiler . 2 (Water heater, 1)		
Appliances for cleansing utensils and bottles . 2		
Sterilizers for bottles, etc. . 2		
Bottling machine . 1		
Capping machine . 1		
Wash bowl, soap, and towel in handling room . 1		
Condition . 6		
Milk-handling machinery . 3		
Pipes, couplings, and pumps . 2		
Cans . 1		
LABORATORY AND EQUIPMENT	2	—
WATER SUPPLY	2	—
Clean and fresh . 1		
Convenient and abundant . 1		
TOTAL	40	—

METHODS	SCORE Perfect	SCORE Allowed
BUILDING	14	—
Cleanliness.		
Floors . 3		
Walls . 2		
Ceilings . 2		
Doors and windows . 1		
Shafting, pulleys, etc. . 1		
Freedom from odors . 2		
Freedom from flies . 3		
APPARATUS	7	—
Cleanliness:		
Thoroughly washed . 3		
Milk-handling machinery . 2		
Pipes, cans, etc. . 1		
Sterilized with steam . 3		
Milk machinery . 2		
Pipes, cans, etc. . 1		
Protected from contamination . 1		
BOTTLES	7	—
Thoroughly washed and rinsed . 3		
Sterilized with steam 15 minutes . 3		
Inverted in clean place . 1		
HANDLING MILK	22	—
Received below 50° F . 3 (50° to 55°, 2) (55° to 60°, 1)		
Rapidity of handling . 2		
Freedom from undue exposure to air . 2		
Cooling . 5		
Promptness . 2		
Below 45° F. . 3 (45° to 50°, 1)		
Capping by machine . 2		
Bottle protected by cover . 1		
Storage: below 45° F. . 4 (45°–50°, 3; 50°–55°, 1)		
Protection during delivery . 2		
Bottle caps sterilized . 1		
INSPECTION	6	—
Bacteriological work . 3		
Inspection of dairies supplying milk . 3 (2 times a year, 2; once a year, 1)		
MISCELLANEOUS	4	—
Cleanliness of attendants . 2 (Personal cleanliness, 1; washable clothing, 1)		
Cleanliness of delivery outfit 2		
TOTAL	60	—

Score for equipment . . . plus score for methods . . . equals TOTAL SCORE . . .

NOTE. — If the conditions in any particular are so exceptionally bad as to be inadequately expressed by a score of "0," the inspector can make a deduction from the total score.

UNITED STATES DEPARTMENT OF AGRICULTURE

Bureau of Animal Industry

DAIRY DIVISION

SANITARY INSPECTION OF STORES HANDLING BULK MILK

Operator. . . . .

Address. . . . .

Gallons sold daily. . . . .

Permit No. . . . .

Date . . . .

Remarks: . . . .

DETAILED SCORE

Equipment	Score		Methods	Score	
	Perfect	Allowed		Perfect	Allowed
Building:			Building:		
Location: Free from contaminating surroundings	2	—	Cleanliness	10	—
Separate room for milk handling	5	—	Floor 3		
Construction	8	—	Wall 2		
Floors tight, smooth, cleanable 1			Ceiling 2		
Walls tight, smooth, cleanable 1			Show cases, shelves, etc. 3		
Ceilings tight, smooth, cleanable 1			Freedom from flies . . .	3	—
Show cases, smooth, free from ledges and crevices 1			Freedom from rubbish .	2	—
Provision for light (10 per cent of floor space) . 1			Air	4	—
Provision for pure air . 1			Freedom from dust . . . 2		
Screens 2			Freedom from odors . . 2		
Utensils	15	—	Utensils	20	—
Construction: Easily cleaned; free from open seams and complicated parts 5			Thoroughly washed and rinsed 10		
Condition: Free from rust, dents, etc. 2			Steamed . . . . 10 (Scalded, 5)		
			Ice Box:		
			Cleanliness of ice box . .	3	—

DETAILED SCORE — *Continued*

EQUIPMENT	SCORE Perfect	SCORE Allowed	METHODS	SCORE Perfect	SCORE Allowed
Facilities for cleaning:			HANDLING:		
Water clean, convenient, and abundant . . 2			Placed on ice as soon as received . . . . . . (Protected, put on ice inside of an hour, 2) (Unprotected, but put on ice inside of an hour, 1)	5	—
Hot water or steam . . 3					
Brushes and washing powder 1					
Protected from flies and dust when not in use . 2					
ICE BOX	10	—	Temperature of milk, below 50 F. . . . . (51–55°, 8; 56–60°, 5; 61–65°, 2)	10	—
Separate ice box for milk . 5 (Milk kept in separate compartment, 2)			Freedom from undue exposure to air	2	—
Construction 3			CLEANLINESS OF ATTENDANTS	1	—
Tight and cleanable . 1					
Nonabsorbent lining 1					
Good drainage . . 1					
Protected from flies and dust 2					
TOTAL	40	—	TOTAL	60	—

Equipment . . . + Methods . . . = Total . . . .

NOTE. — If the conditions in any particular are so exceptionally bad as to be inadequately expressed by a score of "0," the inspector can make a deduction from the total score.

SCORE-CARD FOR MILK

ITEM	PERFECT SCORE	SCORE ALLOWED	REMARKS
Bacteria.	35	. . . .	Bacteria found per cubic centimeter . . . .
Flavor and odor	25	. . . .	Cowy, Bitter, Feed, Flat, Strong . . . .
Visible dirt.	10	. . . .	. . . .
Fat.	10	. . . .	Per cent found. . . . .
Solids not fat.	10	. . . .	Per cent found. . . . .
Acidity.	5	. . . .	Per cent found. . . . .
Bottle and cap.	5	. . . .	Cap. . . . . Bottle. . . . .
TOTAL.	100	. . . .	

DIRECTIONS FOR SCORING

BACTERIA PER CUBIC CENTIMETER — PERFECT SCORE, 35

	Points		Points
Under 500	35	25,001–30,000	29.0
500–1,000	34.9	30,001–35,000	28.0
1,001–1,500	34.8	35,001–40,000	27.0
1,501–2,000	34.7	40,001–45,000	26.0
2,001–2,500	34.6	45,001–50,000	25.0
2,501–3,000	34.5	50,001–55,000	24.0
3,001–3,500	34.4	55,001–60,000	23.0
3,501–4,000	34.3	60,001–65,000	22.0
4,001–5,000	34.0	65,001–70,000	21.0
5,001–6,000	33.8	70,001–75,000	20.0
6,001–7,000	33.6	75,001–80,000	19.0
7,001–8,000	33.4	80,001–85,000	18.0
8,001–9,000	33.2	85,001–90,000	17.0
9,001–10,000	33.0	90,001–95,000	16.0
10,001–11,000	32.8	95,001–100,000	15.0
11,001–12,000	32.6	100,001–120,000	12.5
12,001–13,000	32.4	120,001–140,000	10.0
13,001–14,000	32.2	140,001–160,000	7.5
14,001–15,000	32.0	160,001–180,000	5.0
15,001–20,000	31.0	180,001–200,000	2.5
20,001–25,000	30.0	Above 200,000	0.0

NOTE. — When the number of bacteria per cubic centimeter exceeds the local legal limit the score shall be 0.

FLAVOR AND ODOR — PERFECT SCORE, 25

Deductions for disagreeable or foreign odor or flavor should be made according to conditions found. When possible to recognize the cause of the difficulty it should be described under Remarks.

VISIBLE DIRT — PERFECT SCORE, 10

Examination for visible dirt should be made only after the milk has stood for some time undisturbed in any way. Raise the bottle carefully in its natural, upright position, without tipping, until higher than the head. Observe the bottom of the milk with the naked eye or by the aid of a reading glass. The presence of the slightest movable speck makes a perfect score impossible. Further deductions should be made according to the amount of dirt found. When possible the nature of the dirt should be described under Remarks.

FAT IN MILK — PERFECT SCORE, 10

	Points		Points
4.0 per cent and over	10	3.2 per cent	6
3.9 per cent	9.8	3.1 per cent	5
3.8 per cent	9.6	3.0 per cent	4
3.7 per cent	9.4	2.9 per cent	3
3.6 per cent	9.2	2.8 per cent	2
3.5 per cent	9	2.7 per cent	1
3.4 per cent	8	Less than 2.7 per cent	0
3.3 per cent	7		

NOTE. — When the per cent of fat is less than the local legal limit the score shall be 0.

SOLIDS NOT FAT — PERFECT SCORE, 10

	Points		Points
8.7 per cent and over	10	8.1 per cent	4
8.6 per cent	9	8.0 per cent	3
8.5 per cent	8	7.9 per cent	2
8.4 per cent	7	7.8 per cent	1
8.3 per cent	6	Less than 7.8 per cent	0
8.2 per cent	5		

NOTE. — When the per cent of solids not fat is less than the local legal limit the score shall be 0.

Acidity — Perfect Score, 5

	Points		Points
0.2 per cent and less	5	0.23 per cent	2
0.21 per cent	4	0.24 per cent	1
0.22 per cent	3	Over 0.24 per cent	0

Bottle and Cap — Perfect Score, 5

Bottles should be made of clear glass and free from attached metal parts. Caps should be sealed in their place with hot paraffin, or both cap and top of bottle covered with parchment paper or other protection against water and dirt. Deduct for tinted glass, attached metal parts, unprotected or leaky caps, partially filled bottles, or other conditions permitting contamination of milk or detracting from the appearance of the package.

SCORE-CARD FOR CREAM

Place..

Class ....*Exhibit No*......................

Item	Perfect Score	Score Allowed	Remarks
Bacteria...........	35	....	Bacteria found per cubic centimeter } ....
Flavor and odor	25	....	Cowy, Bitter, Feed, Flat, Strong } ...
Visible dirt.........	10	....	....
Fat................	20	....	Per cent found..........
Acidity............	5	....	Per cent found ....
			Cap..................
Bottle and cap......	5	....	{ Cap.................. Bottle................
Total.......	100	....	

Exhibitor,..

Address,...

(*Signed*)...
Judge.

Date,......................, *191*

DIRECTIONS FOR SCORING

Bacteria per Cubic Centimeter — Perfect Score, 35

	Points		Points
Under 500	35	25,001–30,000	29.0
500–1,000	34.9	30,001–35,000	28.0
1,001–1,500	34.8	35,001–40,000	27.0
1,501–2,000	34.7	40,001–45,000	26.0
2,001–2,500	34.6	45,001–50,000	25.0
2,501–3,000	34.5	50,001–55,000	24.0
3,001–3,500	34.4	55,001–60,000	23.0
3,501–4,000	34.3	60,001–65,000	22.0
4,001–5,000	34.0	65,001–70,000	21.0
5,001–6,000	33.8	70,001–75,000	20.0
6,001–7,000	33.6	75,001–80,000	19.0
7,001–8,000	33.4	80,001–85,000	18.0
8,001–9,000	33.2	85,001–90,000	17.0
9,001–10,000	33.0	90,001–95,000	16.0
10,001–11,000	32.8	95,001–100,000	15.0
11,001–12,000	32.6	100,001–120,000	12.5
12,001–13,000	32.4	120,001–140,000	10.0
13,001–14,000	32.2	140,001–160,000	7.5
14,001–15,000	32.0	160,001–180,000	5.0
15,001–20,000	31.0	180,001–200,000	2.5
20,001–25,000	30.0	Above 200,000	0.0

Note. — When the number of bacteria per cubic centimeter exceeds the local legal limit the score shall be 0.

Flavor and Odor — Perfect Score, 25

Deductions for disagreeable or foreign odor or flavor should be made according to conditions found. When possible to recognize the cause of the difficulty it should be described under Remarks.

Visible Dirt — Perfect Score, 10

Examination for visible dirt should be made only after the milk has stood for some time undisturbed in any way. Raise the bottle carefully in its natural, upright position, without tipping, until higher than the head. Observe the bottom of the milk with the naked eye or by the aid of a reading glass. The presence of the slightest movable speck makes a perfect score impossible. Further deductions should be made according to the amount of dirt found. When possible the nature of the dirt should be described under Remarks.

Fat in Cream — Perfect Score, 20

If 20 per cent fat or above, score perfect. Deduct 1 point for each one-half per cent fat below 20.

Note. — When the per cent of fat is less than the local legal limit the score shall be 0.

Acidity — Perfect Score, 5

	Points		Points
0.2 per cent and less	5	0.23 per cent	2
0.21 per cent	4	0.24 pec cent	1
0.22 per cent	3	Over 0.24 per cent	0

Bottle and Cap — Perfect Score, 5

Bottles should be made of clear glass and free from attached metal parts. Caps should be sealed in their place with hot paraffin, or both cap and top of bottle covered with parchment paper or other protection against water and dirt. Deduct for tinted glass, attached metal parts, unprotected or leaky caps, partially filled bottles, or other conditions permitting contamination of milk or detracting from the appearance of the package.

THE CARE OF MILK IN THE HOME (Whitaker)

If the milk-producer and the milk-dealer have done their duty, there is daily left at the consumer's door a bottle of clean, cold, unadulterated milk. By improper treatment in the home the milk may then become unfit for food, especially for babies. This bad treatment consists (1) in placing it in unclean vessels; (2) in exposing it unnecessarily to the air; (3) in failing to keep it cool up to the time of using it; and (4) in exposing it to flies.

Milk absorbs impurities — collects bacteria — whenever it is exposed to the air or placed in unclean vessels. Some of these may be the bacteria of certain contagious diseases; others may cause digestive troubles which in the case of babies may prove fatal. Much of the cholera infantum and summer bowel troubles of infants is due to impure milk. The amount of the contamination depends largely on the condition of the utensils and the air with which the milk comes in contact; the air of even a so-called clean room contains many impurities. The science of bacteriology is raising the standard of cleanliness of utensils. Bacteria which get into the milk from the air or from the vessels multiply rapidly so long as the milk remains warm; that is, at 50° F. or above. At lower temperatures the bacteria either are dormant or increase slowly. Cleanliness and cold are imperative if one would have good milk, although if it is consumed so quickly after production that the bacteria in it do not have time to increase much — say within two or three hours — the importance of cold is lessened. Milk from the grocery store or bakery which is kept in a can, open much of the time, possibly without refrigeration, is dangerous and should be avoided.

The suggestions given here regarding milk apply also to cream.

Receiving the milk.

The best way of buying milk is in bottles. Dipping milk from large cans and pouring it into customers' receptacles on the street, with all the incident exposure to dusty air not always the cleanest, is a bad practice. Drawing milk from the faucet of a retailer's can is almost as bad as dipping, because, although the milk may be exposed to the street air a little less than by the dipping process, it is not kept thoroughly mixed, and some consumers will receive less than their proportion of cream. If situated so that it is impossible to get bottled milk, do not set out overnight an uncovered vessel to collect thousands of bacteria from street dust before milk is put into it. Have the milk delivered personally to some member of the family if possible; if not, set out a bowl covered with a plate, or better still, use a glass preserving jar in which nothing but milk is put. In the latter case use a jar with a glass top, but omit the rubber band. Paper tickets are often more or less soiled; hence if they are used do not put them in the can, bowl, or jar. For the same reason money should not be put in the can.

Take the milk into the house as soon as possible after delivery, particularly in hot weather. Never allow the sun to shine for any length of time on the milk. Sometimes milk delivered as early as 4 A.M. remains out of doors until 9 or 10 o'clock. This is wrong. If it is inconvenient to receive the milk soon after it is delivered, indicate to the driver a sheltered place, or provide a covered box in which the milk bottle or can may be left.

Handling and keeping milk. (See Plate XI.)

On receiving the milk put it in the refrigerator at once and allow it to remain there when not using from it. Except in cold weather milk cannot be properly kept without ice. Unless the milk bottle is in actual contact with the ice it will be colder at the bottom of the refrigerator than in the ice compartment, as the cold air settles rapidly.

Keep milk in the original bottle till needed for immediate consumption; do not pour it into a bowl or pitcher for storage. Carefully wipe or rinse the bottle, especially the mouth, before pouring any milk from it, so that dust or dirt which may have gathered thereon or on the cap will not get into the milk. Do not pour back into the bottle milk which has been exposed to the air by being placed in other vessels. Keep the bottle covered with a paper cap as long as milk is in it and when not actually pouring from it. If the paper cap has been punctured, cover the bottle with an inverted tumbler.

Milk deteriorates by exposure to the air of pantry, kitchen, or nursery. Do not expose uncovered milk in a refrigerator containing food of any kind, not to mention strong-smelling foods like fish, cabbage, or onions. An excellent way of serving milk on the table, from the sanitary standpoint, is in the original bottle; at all events pour out only what will be consumed at one meal.

When milk is received in a bowl or pitcher instead of in a bottle, observe the spirit of the foregoing remarks: Keep the vessel covered; expose uncovered milk to the air of any room as little as possible; do not expose it at all in a refrigerator.

Remember that exposure of milk to the open air invites contamination not only from odors and bacteria-laden dust, but also from flies. These scavengers may convey germs of typhoid fever or other contagious diseases from the sick room or from excreta to the milk.

Records show typhoid epidemics from such a cause, and 100,000 fecal bacteria have been found on a single fly. Flies also frequently convey to milk large numbers of the bacteria that cause intestinal disorders in infants; an examination of 414 flies showed an average of 1,250,000 bacteria to a fly.

The refrigerator.

Keep the refrigerator clean and sweet. Personally inspect it at least once a week. See that the outlet for water formed

by the melting ice is kept open and that the space under the ice rack is clean. The place where food is kept should be scalded every week; a single drop of spilled milk or a small particle of other neglected food will contaminate a refrigerator in a few days.

Cleaning empty bottles and utensils.

As soon as a milk bottle is empty, rinse it in lukewarm water until it appears clear, then set it bottom up to drain. Do not use it for any other purpose than for milk. There is no objection to the consumer's washing and scalding the milk bottle, but this is unnecessary, as the dealer will wash it again when it reaches his plant. He cannot, however, do this properly if he receives the bottle in a filthy condition; and if you return such a bottle, your negligence may result in the subsequent delivery of contaminated milk to some consumer, possibly yourself.

All utensils with which milk comes in contact should be rinsed, washed, and scalded every time they are used. Use fresh water; do not wash them in dishwater which has been used for washing other utensils or wipe them with an ordinary dish towel — it is better to boil in clean water and set them away unwiped.

When a baby is bottle-fed, every time the feeding bottle and nipple are used they should be rinsed in lukewarm water, washed in hot water, to which a small amount of washing soda has been added, and then scalded. Never use a rubber tube between bottle and nipple, or a bottle with corners.

Contagious disease.

If a case of typhoid fever, scarlet fever, diphtheria, or other contagious disease breaks out in the family, do not return any bottles to the milkman except with tbe knowledge of the attending physician and under conditions prescribed by him.

PASTEURIZATION OF MILK IN THE HOME

Much of the bottled milk which is now delivered in the cities is pasteurized at the city milk plant. While this reduces the germ content and, if properly done, removes danger from disease organisms, there are always some bacteria left in the milk and these will increase rapidly unless the milk is kept cold. Pasteurized milk should receive just as good care as raw milk.

It is frequently desirable to purchase raw milk and pasteurize it in the home. This is especially true when the milk is intended for infant feeding or for young children. While this process requires some care and attention, very satisfactory results can be obtained by the use of the proper methods. A simple method for the home pasteurization of milk is given as follows by Rogers [1] of the Dairy Division at Washington:

"Milk is most conveniently pasteurized in the bottles in which it is delivered. To do this use a small pail with a perforated false bottom. An inverted pie tin with a few holes punched in it will answer this purpose. This will raise the bottles from the bottom of the pail, thus allowing a free circulation of water and preventing bumping of the bottles. Punch a hole through the cap of one of the bottles and insert a thermometer. The ordinary floating type of thermometer is likely to be inaccurate, and if possible a good thermometer with the scale etched on the glass should be used. Set the bottles of milk in the pail and fill the pail with water nearly to the level of the milk. Put the pail on the stove or over a gas flame and heat it until the thermometer in the milk shows not less than 150° nor more than 155° F. The bottles should then be removed from the water and allowed to stand from twenty to thirty minutes. The temperature will fall slowly, but may be held more uniformly by covering the bottles with

[1] B. A. I. Circular No. 197.

a towel. The punctured cap should be replaced with a new one, or the bottle should be covered with an inverted cup.

"After the milk has been held as directed it should be cooled as quickly and as much as possible by setting in water. To avoid danger of breaking the bottle by too sudden change of temperature, this water should be warm at first. Replace the warm water slowly with cold water. After cooling, milk should in all cases be held at the lowest available temperature.

"This method may be employed to retard the souring of milk or cream for ordinary uses. It should be remembered, however, that pasteurization does not destroy all bacteria in milk, and after pasteurization it should be kept cold and in a cleanly manner and used as soon as possible. Cream does not rise as rapidly or separate as completely in pasteurized milk as in raw milk.

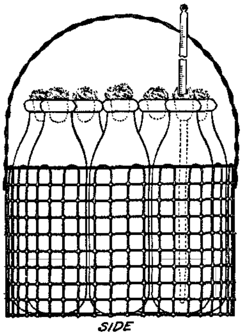


FIG. 43. — Wire basket holding bottles for pasteurization of milk.

"When milk is to be used for infants the pasteurization should be done in the nursing bottle to avoid the possibilities of contamination and the necessity of warming the entire lot of milk each time a feeding is taken. This will require, on account of the smaller bottles, a slightly different method than for ordinary bottles. A bottle should be provided for each feeding with the exact amount of milk required. An extra bottle should also be provided, as there is always the possibility that a bottle will be broken in the process. If the milk is modified this should be done before pasteurization. Bottles not provided with seals may be plugged

with ordinary (not absorbent) cotton and the thermometer held in one of the bottles by the cotton plug. A wire or tin basket to hold the bottles upright in the water is very convenient. Such a device is shown in Fig. 43. Place the bottles in the pail of water and heat until the thermometer shows that the temperature of the milk is 145° to 150° F. Then remove the bottles, change the thermometer from the milk to the water, and add cold water until the temperature of the water is also 145° to 150° F. Put the bottles back in the water and cover with a bath towel or other suitable cloth. Hold in this way at least twenty minutes, and then cool by running water into the pail. When the milk is cooled to the temperature of the tap water it is an excellent plan to pack broken ice about the bottles and hold them in the refrigerator in this way.

"The milk should not be removed until immediately before it is used, and if bottles are warmed and not used they should be discarded."

CHAPTER VII

CERTIFIED MILK

CERTIFIED milk is that which has been produced under the supervision of a Medical Milk Commission and in accordance with the requirements of the Commission. The Milk Commission must be appointed by an approved Medical Society. The Medical Milk Commission employs the services of experts, whose duty it is to make frequent examinations of the milk and methods of production. If the reports of these experts are satisfactory to the Commission, it then issues its certification for the milk in question. The first certified milk was produced in 1891 to meet a need recognized by physicians for a high grade milk for the feeding of infants and young children.

The term "certified milk" is registered in the United States Patent Office in order to protect it from being used to designate any grade of milk which does not conform to the requirements of a medical milk commission. It is distinctly understood, however, that the use of the term shall be allowed without question when employed by medical milk commissions organized to influence dairy work for clinical purposes.

Some states have enacted legislation protecting the use of this term. New York has set a good example by a law a part of which is as follows:

"No person shall sell or exchange, or offer or expose for sale or exchange, as and for certified milk any milk which does not conform to the regulations prescribed by, and bear the certification of, a milk commission appointed by a county medical

society organized under and chartered by the Medical Society of the State of New York and which has not been pronounced by such authority to be free from antiseptics, added preservatives, and pathogenic bacteria in excessive numbers. All milk sold as certified milk shall be conspicuously marked with the name of the commission certifying it."

Certified milk must be regarded as a special product rather than as a part of the regular milk supply. It is used mostly for the feeding of infants and invalids under the direction of a physician. Even in the cities where it is used most, it constitutes less than 1 per cent of the total milk supply. Inasmuch as the retail price to consumers varies in different places from 10 to 20 cents a quart, consumers, generally, have not been willing to pay the additional price necessary to produce milk of this high degree of excellence.

Kelly [1] discusses the value of certified milk as follows:

"While certified milk is in a class by itself and does not enter into competition with ordinary grades of market milk, it has much educational value in cities where it is used. There is no doubt that the advertising of certified milk does much to inform consumers that clean milk costs more than dirty milk and that a cheap milk is apt to be dangerous.

"The influence of certified milk on dairymen in general is little more complex. Certified dairies have certainly shown how to produce the finest grade of milk and have served as models along this line. An unfortunate feature has been that many of them have been operated at a financial loss, and this has had a demoralizing effect upon many dairymen, who have been led to believe that the production of clean milk necessitates the outlay of large sums of money in expensive equipment.

"As would naturally he expected, certified milk with its small number of bacteria will keep sweet for a long time. The theory that clean milk should have a long keeping quality works

[1] U. S. Dept. of Agr. Bul. No. 1.

out in practice. Instances are on record where certified milk has been taken on an ocean voyage and not only brought back in good condition but kept sweet until thirty days old. In fact, it is now a common practice for people when crossing the water or taking a long land journey with infants to take several cases of certified milk with them. They are then reasonably sure of having a constant supply of sweet milk for several days. This has been a great convenience and has given comfort to many people.

"A number of certified-milk dairies in the United States sent exhibits of milk to the Paris Exposition in 1900. The milk kept perfectly sweet for two weeks and in some instances 18 days after being bottled and after a summer journey of 3000 to 4000 miles. Regular delivery bottles were used, the only extra precaution being to use two paper caps instead of one, and to cover the caps with paraffin so as to exclude the air. Of course the milk was carefully packed in ice for shipment, but this was the only means used for preservation.

"The milk and cream contests at the National Dairy Show in recent years have demonstrated the remarkable keeping qualities of certified milk. Some of the samples submitted have come to Chicago from as far as the States of Washington and California, and from various parts of Canada. Though these samples have some of them been over a week old when plated, they have shown remarkably low bacterial counts, in some instances the count being less than 1000 a cubic centimeter. After this milk has been judged it has been kept in cold storage, and some has been consumed over two weeks after its production, when it was found perfectly palatable and apparently unchanged in any way.

"However, it is not advisable to use old milk even though it may taste sweet. Serious consequences may result due to bacterial growth which cannot be detected in the flavor of the milk."

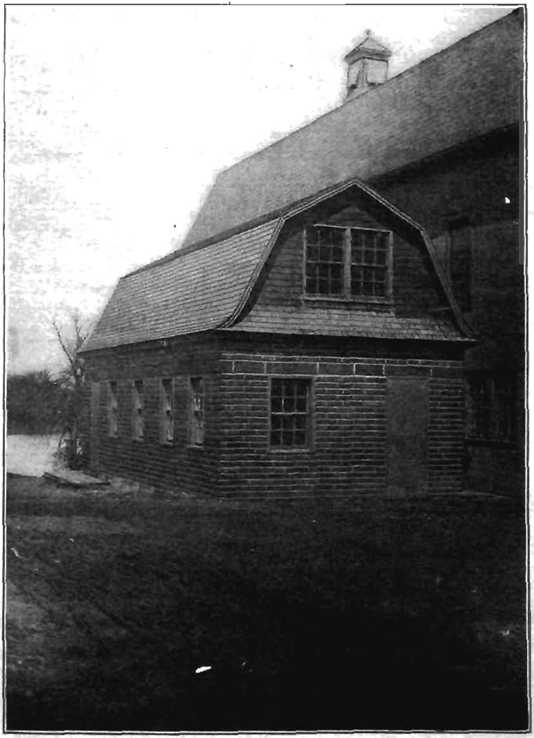


PLATE XII. — Stable and milk-house where "certified" milk is produced.

OBSTACLES TO THE PROFITABLE PRODUCTION OF CERTIFIED MILK (Kelly)

To support the statement that some certified dairies are run under lax business methods, it is only necessary to point to a few figures received by this department. For instance, one dairy reports that the retail price of milk is 20 cents a quart, the average bacterial count is 4000 a cubic centimeter, and that the business is not profitable and it would require a retail price of 25 cents a quart to make it so. Another dairy states that the retail price is only 12 cents, the bacterial count 3000 (less than in the case of the other dairy), and that the business is profitable. There is a difference of 8 cents a quart in favor of the first dairy, and yet with that advantage it is unable to conduct the business at a profit.

Many certified milk producers have erected extremely elaborate buildings, the interest and depreciation on which are so high that they form a considerable item to be charged against the cost of production. The interest and depreciation on a simple, inexpensive certified plant is estimated to amount to at least 6 cents a gallon, or 1½ cents a quart. In some of the more elaborate plants, where much money has been spent for ornamental equipment, the interest and depreciation would be much higher. Experience in the past has proved that the production of clean milk is not dependent upon expensive equipment so much as upon care and vigilance concerning the methods of production. It is a well-known fact in business that a manufacturing plant cannot afford to turn out such a small quantity of goods that the interest and depreciation on the factory will be too heavy a tax on the goods sold. Applying this same principle to dairying, it is almost impossible to see where some of the small dairies can afford to operate as they do. One dairy reports that they are selling only 12½ quarts of certified milk a day, and the interest and depreciation on the

capital invested in this plant will certainly amount to quite a large item per quart on all the milk sold. Another plant reports a daily selling of 30 quarts, and another of only 120 quarts.

The average production of milk per cow in certified dairies shows that many unprofitable animals are probably being kept, and a thorough system of record keeping should be inaugurated in order to weed out the low producers. One dairy reports that the average test of the milk is 6 per cent fat, and it is hard to see how such milk can be profitably sold in competition with 4 per cent milk. In order to improve the herds from year to year calves should be raised from the best producing cows. Here again is another item of added expense on the certified dairy, as the raising of calves is an expensive proposition, especially where milk valued at from 15 to 20 cents a quart is used. If calves are not raised and cows are bought from the outside, there is little chance of bettering the herd.

On most certified farms a higher class of labor is utilized than on the ordinary dairy farm. Many college graduates are employed as foremen, managers, or bacteriologists, and such men usually command higher salaries.

Markets for certified milk at the present time are not developed sufficiently. Several of the certified dairies reporting that the production of this product was unprofitable intimated that if more milk could be sold and the plant operated at a greater capacity a profit might be realized. The general public so far has very little idea as to what certified milk really is, and an educational campaign might well be carried on by the producers. In addition to this, lax methods on some farms have necessitated a high price for certified milk, and this has cut down the consumption considerably.

There seems to be little uniformity regarding the distribution of certified milk. Some of the methods now in vogue seem to be to the disadvantage of the producer. Of the producers re-

porting, twenty-five retail the product of their dairies, while forty-seven do not. From the answers received it appears to be more economical to distribute through a middleman, especially where the points of production and distribution are widely separated. The middleman has the advantage of already maintaining an establishment in the city and of running regular retail routes on which the certified milk can be distributed quite economically. Some of these distributors of certified milk seem to charge the producer a rather high rate for their services. Many city dealers buy market milk from farmers and receive from 14 to 19 cents a gallon to cover the cost of freight, bottling, and distribution, besides giving them their profit. Certified milk is nearly always bottled at the farm, so that the expense of handling in the city is much smaller. Figures submitted to this department, however, show out of 50 cents a gallon paid by consumers for certified milk from one farm, the producer got 26 cents, the freight was 4 cents, and the middleman charged 20 cents a gallon for his services in distributing the product. Another dairy receives 12 cents out of a retail price of 15 cents a quart, leaving the distributor 12 cents a gallon. In one case the middleman received 5 cents a quart for distribution, while the other received 3 cents.

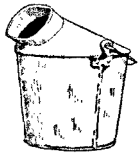


Fig. 44.—The Francisco small top pail suitable for the production of certified milk.

THE FUTURE OF CERTIFIED MILK (Kelly)

There is no doubt that from a sanitary standpoint certified milk is constantly improving, and it will undoubtedly continue to lead all classes of milk as a food for infants. It seems almost imperative, however, that business principles be more closely applied to the production of certified milk, so that the price may be kept as low as possible to the consumer and still

let the farmers operate at a profit. Upon this one factor depends much of the future growth of the movement. It is very probable that certified-milk producers in the future will apply the same degree of intelligence and care to the economic features of their business as they have in the past to the sanitary side.

The official methods and standards for the production and handling of certified milk are as follows:

METHODS AND STANDARDS FOR THE PRODUCTION AND DISTRIBUTION OF CERTIFIED MILK

(Adopted by the American Association of Medical Milk Commissions, May 1, 1912)

HYGIENE OF THE DAIRY

UNDER THE SUPERVISION AND CONTROL OF THE VETERINARIAN

1. *Pastures or paddocks.* — Pastures or paddocks to which the cows have access shall be free from marshes or stagnant pools, crossed by no stream which might become dangerously contaminated, at sufficient distances from offensive conditions to suffer no bad effects from them, and shall be free from plants which affect the milk deleteriously.

2. *Surroundings of buildings.* — The surroundings of all buildings shall be kept clean and free from accumulations of dirt, rubbish, decayed vegetable or animal matter or animal waste, and the stable yard shall be well drained.

3. *Location of buildings.* — Buildings in which certified milk is produced and handled shall be so located as to insure proper shelter and good drainage, and at sufficient distance from other buildings, dusty roads, cultivated and dusty fields, and all other possible sources of contamination; provided in the case of unavoidable proximity to dusty roads or fields, the exposed side shall be screened with cheesecloth.

4. *Construction of stables.* — The stables shall be constructed so as to facilitate the prompt and easy removal of waste products. The floors and platforms shall be made of cement or other nonabsorbent material aud the gutters of cement only. The floors shall be properly graded and drained, and the manure gutters shall be from 6 to 8 inches deep and so placed in relation to the platform that all manure will drop into them.

5. The inside surface of the walls and all interior construction shall be smooth, with tight joints, and shall be capable of shedding water. The ceiling shall be of smooth material and dust tight. All horizontal and slanting surfaces which might harbor dust shall be avoided.

6. *Drinking and feed troughs.* — Drinking troughs or basins shall be drained and cleaned each day, and feed troughs and mixing floors shall be kept in a clean and sanitary condition.

7. *Stanchions.* — Stanchions, when used, shall be constructed of iron pipes or hardwood, and throat latches shall be provided to prevent the cows from lying down between the time of cleaning and the time of milking.

8. *Ventilation.* — The cow stables shall be provided with adequate ventilation either by means of some approved artificial device, or by the substitution of cheesecloth for glass in the windows, each cow to be provided with a minimum of 600 cubic feet of air space.

9. *Windows.* — A sufficient number of windows shall be installed and so distributed as to provide satisfactory light and a maximum of sunshine, 2 feet square of window area to each 600 cubic feet of air space to represent the minimum. The coverings of such windows shall be kept free from dust and dirt.

10. *Exclusion of flies, etc.* — All necessary measures should be taken to prevent the entrance of flies and other insects and rats and other vermin into all the buildings.

11. *Exclusion of animals from the herd.* — No horses, hogs, dogs, or other animals or fowls shall be allowed to come in contact with the certified herd, either in the stables or elsewhere.

12. *Bedding.* — No dusty or moldy hay or straw, bedding from horse stalls, or other unclean materials shall be used for bedding the cows. Only bedding which is clean, dry, and absorbent may be used, preferably shavings or straw.

13. *Cleaning stable and disposal of manure.* — Soiled bedding and manure shall be removed at least twice daily, and the floors shall be swept and kept free from refuse. Such cleaning shall be done at least one hour before the milking time. Manure, when removed, shall be drawn to the field or temporarily stored in containers so screened as to exclude flies. Manure shall not be even temporarily stored within 300 feet of the barn or dairy building.

14. *Cleaning of cows.* — Each cow in the herd shall be groomed daily, and no manure, mud, or filth shall be allowed to remain upon her during milking; for cleaning, a vacuum apparatus is recommended.

15. *Clipping.* — Long hairs shall be clipped from the udder and flanks of the cow and from the tail above the brush. The hair on the tail shall be cut so that the brush may be well above the ground.

16. *Cleaning of udders.* — The udders and teats of the cow shall be cleaned before milking; they shall be washed with a cloth and

water, and dry wiped with another clean sterilized cloth — a separate cloth for drying each cow.

17. *Feeding.* — All foodstuffs shall be kept in an apartment separate from and not directly communicating with the cow barn. They shall be brought into the barn only immediately before the feeding hour, which shall follow the milking.

18. Only those foods shall be used which consist of fresh, palatable, or nutritious materials, such as will not injure the health of the cows or unfavorably affect the taste or character of the milk. Any dirty or moldy food or food in a state of decomposition or putrefaction shall not be given.

19. A well-balanced ration shall be used, and all changes of food shall be made slowly. The first few feedings of grass, alfalfa, ensilage, green corn, or other green feeds shall be given in small rations and increased gradually to full ration.

20. *Exercise.* — All dairy cows shall be turned out for exercise at least 2 hours in each 24 in suitable weather. Exercise yards shall be kept free from manure and other filth.

21. *Washing of hands.* — Conveniently located facilities shall be provided for the milkers to wash in before and during milking.

22. The hands of the milkers shall be thoroughly washed with soap, water, and brush and carefully dried on a clean towel immediately before milking. The hands of the milkers shall be rinsed with clean water and carefully dried before milking each cow. The practice of moistening the hands with milk is forbidden.

23. *Milking clothes.* — Clean overalls, jumper, and cap shall be worn during milking. They shall be washed or sterilized each day and used for no other purpose, and when not in use they shall be kept in a clean place, protected from dust and dirt.

24. *Things to be avoided by milkers.* — While engaged about the dairy or in handling the milk employees shall not use tobacco nor intoxicating liquors. They shall keep their fingers away from their nose and mouth, and no milker shall permit his hands, fingers, lips, or tongue to come in contact with milk intended for sale.

25. During milking the milkers shall be careful not to touch anything but the clean top of the milking stool, the milk pail, and the cow's teats.

26. Milkers are forbidden to spit upon the walls or floors of stables, or upon the walls or floors of milk houses, or into the water used for cooling the milk or washing the utensils.

27. *Fore milk.* — The first streams from each teat shall be rejected, as this fore milk contains large numbers of bacteria. Such milk shall be collected into a separate vessel and not milked on to the floors or into the gutters. The milking shall be done rapidly and quietly, and the cows shall be treated kindly.

28. *Milk and calving period.* — Milk from all cows shall be excluded for a period of 45 days before and 7 days after parturition.

29 *Bloody and stringy milk.* — If milk from any cow is bloody and stringy or of unnatural appearance, the milk from that cow shall be rejected and the cow isolated from the herd until the cause of such abnormal appearance has been determined and removed, special attention being given in the meantime to the feeding or to possible injuries. If dirt gets into the pail, the milk shall be discarded and the pail washed before it is used.

30. *Make-up of herd.* No cows except those receiving the same supervision and care as the certified herd shall be kept in the same barn or brought in contact with them.

31. *Employees other than milkers.* The requirements for milkers, relative to garments and cleaning of hands, shall apply to all other persons handling the milk, and children unattended by adults shall not be allowed in the dairy nor in the stable during milking.

32. *Straining and strainers.* — Promptly after the milk is drawn it shall be removed from the stable to a clean room and then emptied from the milk pail to the can, being strained through strainers made of a double layer of finely meshed cheesecloth or absorbent cotton thoroughly sterilized. Several strainers shall be provided for each milking in order that they may be frequently changed.

33. *Dairy building.* — A dairy building shall be provided which shall be located at a distance from the stable and dwelling prescribed by the local commission, and there shall be no hogpen, privy, or manure pile at a higher level or within 300 feet of it.

34. The dairy building shall be kept clean and shall not be used for purposes other than the handling and storing of milk and milk utensils. It shall be provided with light and ventilation, and the floors shall be graded and water-tight.

35. The dairy building shall be well lighted and screened and drained through well-trapped pipes. No animals shall be allowed therein. No part of the dairy building shall be used for dwelling or lodging purposes, and the bottling room shall be used for no other purpose than to provide a place for clean milk utensils and for handling the milk. During bottling this room shall be entered only by persons employed therein. The bottling room shall be kept scrupulously clean and free from odors.

36. *Temperature of milk.* — Proper cooling to reduce the temperature to 45° F. shall be used, and aërators shall be so situated that they can be protected from flies, dust, and odors. The milk shall be cooled immediately after being milked, and maintained at a temperature between 35° and 45° F. until delivered to the consumer.

37. *Sealing of bottles.* — Milk, after being cooled and bottled, shall be immediately sealed in a manner satisfactory to the commission,

but such seal shall include a sterile hood which completely covers the lip of the bottle.

38. *Cleaning and sterilizing of bottles.* -- The dairy building shall be provided with approved apparatus for the cleansing and sterilizing of all bottles and utensils used in milk production. All bottles and utensils shall be thoroughly cleaned by hot water and sal soda, or equally pure agent, rinsed until the cleaning water is thoroughly removed, then exposed to live steam or boiling water at least 20 minutes, and then kept inverted until used, in a place free from dust and other contaminating materials.

39. *Utensils.* All utensils shall be so constructed as to be easily cleaned. The milk pail should preferably have an elliptical opening 5 by 7 inches in diameter. The cover of this pail should be so convex as to make the entire interior of the pail visible and accessible for cleaning. The pail shall be made of heavy seamless tin, and with seams which are flushed and made smooth by solder. Wooden pails, galvanized-iron pails, or pails made of rough, porous materials, are forbidden. All utensils used in milking shall be kept in good repair.

40. *Water supply.* -- The entire water supply shall be absolutely free from contamination, and shall be sufficient for all dairy purposes. It shall be protected against flood or surface drainage, and shall be conveniently situated in relation to the milk house.

41. *Privies, etc., in relation to water supply.* -- Privies, pigpens, manure piles, and all other possible sources of contamination shall be so situated on the farm as to render impossible the contamination of the water supply, and shall be so protected by use of screens and other measures as to prevent their becoming breeding grounds for flies.

42. *Toilet rooms.* -- Toilet facilities for the milkers shall be provided and located outside of the stable or milk house. These toilets shall be properly screened, shall be kept clean, and shall be accessible to wash basins, water, nail brush, soap, and towels, and the milkers shall be required to wash and dry their hands immediately after leaving the toilet room.

Transportation

43. In transit the milk packages shall be kept free from dust and dirt. The wagon, trays, and crates shall be kept scrupulously clean. No bottles shall be collected from houses in which communicable diseases prevail, unless a separate wagon is used and under conditions prescribed by the department of health and the medical milk commission.

44. All certified milk shall reach the consumer within 30 hours after milking.

Veterinary Supervision of the Herd

45. *Tuberculin test.* — The herd shall be free from tuberculosis, as shown by the proper application of the tuberculin test. The test shall be applied in accordance with the rules and regulations of the United States Government, and all reactors shall be removed immediately from the farm.[1]

46. No new animals shall be admitted to the herd without first having passed a satisfactory tuberculin test, made in accordance with the rules and regulations mentioned; the tuberculin to be obtained and applied only by the official veterinarian of the commission.

47. Immediately following the application of the tuberculin test to a herd for the purpose of eliminating tuberculous cattle, the cow stable and exercising yards shall be disinfected by the veterinary inspector in accordance with the rules and regulations of the United States Government.

48. A second tuberculin test shall follow each primary test after an interval of six months, and shall be applied in accordance with the rules and regulations mentioned. Thereafter, tuberculin tests shall be reapplied annually, but it is recommended that the retests be applied semiannually.

49. *Identification of cows.* — Each dairy cow in each of the certified herds shall be labeled or tagged with a number or mark which will permanently identify her.

50. *Herd-book record.* — Each cow in the herd shall be registered in a herd book, which register shall be accurately kept so that her entrance and departure from the herd and her tuberculin testing can be identified.

51. A copy of this herd-book record shall be kept in the hands of the veterinarian of the medical milk commission under which the dairy farm is operating, and the veterinarian shall be made responsible for the accuracy of this record.

52. *Dates of tuberculin tests.* — The dates of the annual tuberculin tests shall be definitely arranged by the medical milk commission, and all of the results of such tests shall be recorded by the veterinarian and regularly reported to the secretary of the medical milk commission issuing the certificate.

53. The results of all tuberculin tests shall be kept on file by each medical milk commission, and a copy of all such tests shall be made available to the American Association of Medical Milk Commissions for statistical purposes.

[1] See Circular of Instructions issued by the Bureau of Animal Industry for making tuberculin tests and for disinfection of premises.

54. The proper designated officers of the American Association of Medical Milk Commissions should receive copies of reports of all of the annual, semiannual, and other official tuberculin tests which are made and keep copies of the same on file and compile them annually for the use of the association.

55. *Disposition of cows sick with diseases other than tuberculosis.*— Cows having rheumatism, leucorrhea, inflammation of the uterus, severe diarrhea, or disease of the udder, or cows that from any other cause may be a menace to the herd shall be removed from the herd and placed in a building separate from that which may be used for the isolation of cows with tuberculosis, unless such building has been properly disinfected since it was last used for this purpose. The milk from such cows shall not be used nor shall the cows be restored to the herd until permission has been given by the veterinary inspector after a careful physical examination.

56. *Notification of veterinary inspector.* — In the event of the occurrence of any of the diseases just described between the visits of the veterinary inspector, or if at any time a number of cows become sick at one time in such a way as to suggest the outbreak of a contagious disease or poisoning, it shall be the duty of the dairyman to withdraw such sickened cattle from the herd, to destroy their milk, and to notify the veterinary inspector by telegraph or telephone immediately.

57. *Emaciated cows.* — Cows that are emaciated from chronic diseases or from any cause that in the opinion of the veterinary inspector may endanger the quality of the milk, shall be removed from the herd.

Bacteriological Standards

58. *Bacterial counts.* — Certified milk shall contain less than 10,000 bacteria per cubic centimeter when delivered. In case a count exceeding 10,000 bacteria per cubic centimeter is found, daily counts shall be made, and if normal counts are not restored within 10 days the certificate shall be suspended.

59. Bacterial counts shall be made at least once a week.

60. *Collection of samples.* — The samples to be examined shall be obtained from milk as offered for sale and shall be taken by a representative of the milk commission. The samples shall be received in the original packages, in properly iced containers, and they shall be so kept until examined, so as to limit as far as possible changes in their bacterial content.

61. For the purpose of ascertaining the temperature, a separate original package shall be used, and the temperature taken at the time of collecting the sample, using for the purpose a standardized thermometer graduated in the centigrade scale.

62. *Interval between milking and plating.* — The examinations shall be made as soon after collection of the samples as possible, and in no case shall the interval between milking and plating the samples be longer than 40 hours.

63. *Plating.* — The packages shall be opened with aseptic precautions after the milk has been thoroughly mixed by vigorously reversing and shaking the container 25 times.

64. Two plates at least shall be made for each sample of milk, and there shall also be made a control of each lot of medium and apparatus used at each testing. The plates shall be grown at 37° C. for 48 hours.

65. In making the plates there shall be used agar-agar media containing 1.5 per cent agar and giving a reaction of 1.0 to phenolphthalein.

66. Samples of milk for plating shall be diluted in the proportion of 1 part of milk to 99 parts of sterile water; shake 25 times and plate 1 c.c. of the dilution.

67. *Determination of taste and odor of milk.* — After the plates have been prepared and placed in the incubator, the taste and odor of the milk shall be determined after warming the milk to 100° F.[1]

68. *Counts.* — The total number of colonies on each plate should be counted, and the results expressed in multiples of the dilution factor. Colonies too small to be seen with the naked eye or with slight magnification shall not be considered in the count.

69. *Records of bacteriologic tests.* — The results of all bacterial tests shall be kept on file by the secretary of each commission, copies of which should be made available annually for the use of the American Association of Medical Milk Commissions.

Chemical Standards and Methods

The methods that must be followed in carrying out the chemical investigations essential to the protection of certified milk are so complicated that in order to keep the fees of the chemist at a reasonable figure, there must be eliminated from the examination those procedures which, whilst they might be helpful and interesting, are in no sense necessary.

For this reason the determination of the water, the total solids, and the milk-sugar is not required as a part of the routine examination.

70. The chemical analyses shall be made by a competent chemist designated by the medical milk commission.

[1] Should it be deemed desirable and necessary to conduct tests for sediment, the presence of special bacteria, or the number of leucocytes, the methods adopted by the committee of the American Public Health Association should be followed.

71. *Method of obtaining samples.* — The samples to be examined by the chemist shall have been examined previously by the bacteriologist designated by the medical milk commission as to temperature, odor, taste, and bacterial content.

72. *Fat standards.* — The fat standard for certified milk shall be 4 per cent, with a permissible range of variation of from 3.5 to 4.5 per cent.

73. The fat standard for certified cream shall be not less than 18 per cent.

74. If it is desired to sell higher fat-percentage milks or creams as certified milks or creams, the range of variation for such milks shall be 0.5 per cent on either side of the advertised percentage and the range of variations for such creams shall be 2 per cent on either side of the advertised percentage.

75. The fat content of certified milks and creams shall be determined at least once each month.

76. The methods recommended for this purpose are the Babcock, the Leffmann-Beam, and the Gerber.

77. Before condemning samples of milk which have fallen outside the limits allowed, the chemist shall have determined, by control other extractions, that his apparatus and his technique are reliable.

78. *Protein standard.* — The protein standard for certified milk shall be 3.50 per cent, with a permissible range of variation of from 3 to 4 per cent.

79. The protein standard for certified cream shall correspond to the protein standard for certified milk.

80. The protein content shall be determined only when any special consideration seems to the medical milk commission to make it desirable.

81. It shall be determined by the Kjeldahl method, using the Gunning or some other reliable modification, and employing the factor 6.25 in reckoning the protein from the nitrogen.

82. *Coloring matter and preservatives.* — All certified milks and creams shall be free from adulteration, and coloring matter and preservatives shall not be added thereto.

83. Tests for the detection of added coloring matter shall be applied whenever the color of the milk or cream is such as to arouse suspicion.

84. Tests for the detection of formaldehyde, borax, and boracic acid shall be applied at least once each month. Occasionally application of tests for the detection of salicylic acid, benzoic acid, and the benzoates is also recommended.

85. *Detection of heated milk.* — Certified milk or cream shall not be subjected to heat unless specially directed by the commission to meet emergencies.

86. Tests to determine whether such milks and creams have been subjected to heat shall be applied at least once each month.

87. *Specific gravity.* — The specific gravity of certified milk shall range from 1.029 to 1.034.

88. The specific gravity shall be determined at least each month.

Methods and Regulations for the Medical Examination of Employees: their Health and Personal Hygiene

89. A medical officer, known as the attending dairy physician, shall be selected by the commission, who should reside near the dairy producing certified milk. He shall be a physician in good standing and authorized by law to practice medicine; he shall be responsible to the commission and subject to its direction. In case more than one dairy is under the control of the commission and they are in different localities, a separate physician should be designated for employment for the supervision of each dairy.

90. Before any person shall come on the premises to live and remain as an employee, such person, before being engaged in milking or the handling of milk, shall be subjected to a complete physical examination by the attending physician. No person shall be employed who has not been vaccinated recently or who upon examination is found to have a sore throat, or to be suffering from any form of tuberculosis, venereal disease, conjunctivitis, diarrhea, dysentery, or who has recently had typhoid fever or is proved to be a typhoid carrier, or who has any inflammatory disease of the respiratory tract, or any suppurative process or infectious skin eruption, or any disease of an infectious or contagious nature, or who has recently been associated with children sick with contagious disease.

91. In addition to ordinary habits of personal cleanliness all milkers shall have well-trimmed hair, wear close-fitting caps, and have clean-shaven faces.

92. When the milkers live upon the premises their dormitories shall be constructed and operated according to plans approved by the commission. A separate bed shall be provided for each milker and each bed shall be kept supplied with clean bedclothes. Proper bathing facilities shall be provided for all employees on the dairy premises, preferably a shower bath, and frequent bathing shall be enjoined.

93. In case the employees live on the dairy premises a suitable building shall be provided to be used for the isolation and quarantine of persons under suspicion of having a contagious disease.

94. In the event of any illness of a suspicious nature the attending physician shall immediately quarantine the suspect, notify the health authorities and the secretary of the commission, and examine each member of the dairy force, and in every inflammatory affection of the nose or throat occurring among the employees of the dairy, in addi-

tion to carrying out the above-mentioned program, the attending physician shall take a culture and have it examined at once by a competent bacteriologist approved by the commission. Pending such examination, the affected employee or employees shall be quarantined.

95. It shall be the duty of the secretary, on receiving notice of any suspicious or contagious disease at the dairy, at once to notify the committee having in charge the medical supervision of employees of the dairy farm upon which such disease has developed. On receipt of the notice this committee shall assume charge of the matter, and shall have power to act for the commission as its judgment dictates. As soon as possible thereafter, the committee shall notify the commission, through its secretary, that a special meeting may be called for ultimate consideration and action.

96. When a case of contagious disease is found among the employees of a dairy producing certified milk under the control of a medical milk commission, such employee shall be at once quarantined and as soon as possible removed from the plant, and the premises fumigated.

When a case of contagion is found on a certified dairy it is advised that a printed notice of the facts shall be sent to every householder using the milk, giving in detail the precautions taken by the dairyman under the direction of the commission, and it is further advised that all milk produced at such dairy shall be heated at 145° F. for 40 minutes, or 155° F. for 30 minutes, or 167° F. for 20 minutes, and immediately cooled to 50° F. These facts should also be part of the notice, and such heating of the milk should be continued during the accepted period of incubation for such contagious disease.

The following method of fumigation is recommended:

After all windows and doors are closed and the cracks sealed by strips of paper applied with flour paste, and the various articles in the room so hung or placed as to be exposed on all sides, preparations should be made to generate formaldehyde gas by the use of 20 ounces of formaldehyde and 10 ounces of permanganate of potash for every 1000 cubic feet of space to be disinfected.

For mixing the formaldehyde and potassium permanganate a large galvanized-iron pail or cylinder holding at least 20 quarts and having a flared top should be used for mixing therein 20 ounces of formaldehyde and 10 ounces of permanganate. A cylinder at least 5 feet high is suggested. The containers should be placed about in the rooms and the necessary quantity of permanganate weighed and placed in them. The formaldehyde solution for each pail should then be measured into a wide-mouthed cup and placed by the pail in which it is to be used.

Although the reaction takes place quickly, by making preparations as advised all of the pails can be "set off" promptly by one person, since there is nothing to do but pour the formaldehyde solution over

the permanganate. *The rooms should be kept closed for four hours.* As there is a slight danger of fire, the reaction should be watched through a window or the pails placed on a noninflammable surface.

97. Following a weekly medical inspection of the employees, a monthly report shall be submitted to the secretary of the medical milk commission, on the same recurring date by the examining visiting physician.

CHAPTER VIII

BUTTER-MAKING

BUTTER is composed chiefly of milk-fat which has been separated from most of the other constituents by the process of separation and churning. The principal constituents of butter in addition to the fat are water, salt, casein, and ash, whose percentage will vary with the methods of manufacture. The following figures represent the normal composition of American butter:

AVERAGE COMPOSITION OF CREAMERY BUTTER (B. A. I. Bul. 149)

STATE	NO. OF ANALYSES	FAT	WATER	SALT	CURD
		per cent	*per cent*	*per cent*	*per cent*
Minnesota	223	82.81	13.60	2.34	1.24
Wisconsin	117	82.48	13.77	2.61	1.14
Iowa	131	82.11	14.24	2.51	1.12
California	95	82.12	14.19	2.64	1.05
Pennsylvania . .	37	82.81	13.53	2.63	1.03
North Dakota . .	17	82.40	13.63	2.81	1.15
Texas	15	82.76	13.98	2.15	1.11
Michigan	10	80.99	14.44	3.31	1.26

The average composition of the 695 samples used in this study was found to be: fat 82.41 per cent, water 13.90 per cent, salt 2.51 per cent, curd 1.18 per cent. While the larger number

of samples did not vary widely from these average figures, some rather wide variations were found. Thus, the extremes in percentage were: fat, 73.49 and 87.39; moisture, 10.13 and 20.65; salt, 0.68 and 5.65 and curd, 0.12 and 3.42. Lee found the average composition of 574 samples of butter collected from several states during a period of one year to be: water 13.54 per cent, fat 83.20 per cent, salt 2.25 per cent, and casein and ash 0.9 per cent. These figures represent the normal composition of butter. The composition will vary according to the methods used in its manufacture and within certain limits can be controlled by the butter-maker. The fat does not usually vary more than 3 or 4 per cent. The salt may be varied at will, but usually is between 1.5 and 3.5 per cent. The normal variation for the curd or casein is from about 0.6 per cent to 1.5 per cent. The greatest variation occurs in the water, which may vary from 12 per cent to nearly 16 per cent, that being the legal limit for this constituent. Ordinary variations in composition do not affect the quality of the butter nearly as much as does the quality of the cream used or the methods of manufacture.

CREAMING

For butter-making the milk-fat is removed from the milk in the form of cream which should contain from about 30 per cent to about 45 or possibly 50 per cent of fat. This separation of the fat in the form of cream is possible, because of the difference in the specific gravity between the fat globules and the other constituents of the milk. If milk is allowed to stand undisturbed, the fat globules will slowly rise to the surface and can then be skimmed off in the form of cream, the rapidity and completeness with which the fat globules rise to the surface depending on the difference in specific gravity between the fat globules and the other elements in the milk, and on the viscosity of the milk-serum. Anything which affects either of these

factors will affect the creaming process. The conditions which most commonly affect the creaming process are: the size of the fat globules, the percentage of solids not fat, and the viscosity of the serum. The larger the fat globules, the more easily they rise to the surface, because of the greater mass in proportion to the surface. For this reason, the milk from certain breeds, as the Jersey and Guernsey, creams more easily than that of others, as the Ayrshire and Holsteins. Since the fat globules decrease in size as the lactation period advances, the milk from new milch cows will cream more easily than that of cows far advanced in the period of lactation.

Since the solids not fat are all heavier than water, their increase will increase the specific gravity of the milk-serum and increase the difference in specific gravity of the fat globules and the serum, thus making it easier for the cream to rise. However, an increase in solids increases the viscosity of the serum and retards the rising of the cream. The presence of fibrin in the milk may also interfere with the creaming process. Regarding the influence of fibrin upon the creaming process, Babcock [1] says:

"As the clots of fibrin are heavier than the milk-serum and become attached not only to the fat globules, but to other solid particles in the milk, often to the sides of the vessel in which the milk is set, it is evident that even the small amount of fibrin in milk may be a great hindrance to thorough creaming. If this is true, the most efficient creaming should be obtained when the conditions are such as to oppose the coagulation of fibrin. This is believed to be true in all gravity systems of creaming, at least all improvements which have been made in these systems have been in this direction. The centrifugal separator accomplishes the same end by making the effective difference between the weight of fat and the fibrin clots so great that the disadvantage is overcome, the fibrin being to a considerable

[1] Wis. Report, 1893, p. 145.

extent separated. The fibrin clots, being heavy, accumulate upon the bowl of the separator and make up a large part of the slime which is found after large quantities of milk have been run through."

Methods of creaming

Several methods for separating the cream from the milk are in use. The oldest method is to pour the milk in pans to the depth of 2 to 4 inches and allow it to stand undisturbed for twenty-four to thirty-six hours, at which time the cream can be removed from the surface by means of a shallow skimmer. While newer methods have largely replaced this one, it is still in general use in some sections. The creaming process is never complete by this method and from 0.5 to 1.0 per cent of the cream may be left in the skim-milk. One of the difficulties in this system is that the casein frequently curdles before the fat globules have all risen, thus interfering with complete creaming. To avoid this, what is known as the "deep setting system" was devised. In this system, the milk is placed in cans 8 to 10 inches in diameter and about 20 inches deep; the cans are set in cold water and the milk thus cooled to the temperature of cold well water or ice water. This cooling checks the growth of the bacteria, and prevents the souring and curdling of the milk. According to Babcock, the immediate cooling also prevents the formation of the fibrin clots and threads, making it easier for the fat globules to rise. But this theory is not borne out by Wing,[1] who found that delay in setting did not affect the completeness of creaming. One of the best forms of the deep setting system is the Cooley Creamer in which the cans are completely submerged in ice water. This can is so designed that the skim-milk can be drawn off at the bottom without disturbing the cream. In this way, less fat is lost in the skim-milk than when the cream is removed from the

[1] C. U. Bul. 29, p. 73.

surface by the use of a dipper. The loss of fat in this system is much less than in the shallow pan method, the skimmed milk usually containing not more than 0.2 per cent of fat. Setting in cold water also gives a cream of better quality than that from the shallow pan system.

Water dilution method

In this method, water, either hot or cold, is added directly to the fresh milk, the amount added usually being from one-fourth to one-third the volume of the milk. This method is based on the theory that the dilution lessens the viscosity of the milk, thus making it easier for the fat globules to rise to the surface. Cans of special form, known as "gravity or dilution separators," have been devised for use in this system of creaming. As the result of extended studies with these separators, Wing[1] draws the following conclusions:

"Gravity or dilution separators are merely tin cans in which the separation of cream by gravity process is claimed to be aided by dilution with water.

"Under ordinary conditions the dilution is of no benefit. It may be of some use when the milk is all from 'stripper' cows, or when the temperature of melting ice cannot be secured. (C. U. Agr. Exp. Sta. Bul. 39.)

"These cans are not 'separators' in the universally accepted sense of that term and cannot rank in efficiency with them.

"They are even less efficient than the best forms of deep setting systems, such as the Cooley Creamer.

"They are no more efficient than the old fashioned shallow pan; but perhaps require rather less labor.

"In all probability they would give better results if used without dilution and immersed in as cold water as possible, preferably ice water."

[1] C. U. Bul. 151.

Centrifugal creaming

In recent years, the centrifugal cream separator has taken the place of the older gravity methods except where butter is made on the farm, and in many cases even there. The action of the centrifugal separator is dependent on the same principle as the separation by gravity, *e.g.* the difference in specific gravity of the fat and milk-serum, but in the case of the separator the force is increased many fold by the centrifugal force of the rapidly revolving bowl. As the milk passes through the bowl, the heavier milk-serum is thrown to the outside of the column while the fat globules remain at the center. The cream mav then be removed through one outlet at the center and the skim-milk from another at the outer edge of the bowl. While the various makes of machines differ greatly in style and size, the essential principle is the same in them all. With the possible exception of the Babcock test, no one invention has done more to revolutionize dairy practices, especially butter-making, than has the development of the modern cream separator. This method has many advantages over the older gravity methods, the more important being as follows: (1) More complete separation of the butter-fat. Many machines will not leave over .01 of 1 per cent of fat in the skim-milk. (2) The thickness of the cream may be regulated to suit the purpose for which it is to be used. (3) The cream may be obtained fresh and of much better quality. (4) Saving in time and labor. (5) The fresh skim-milk is available for stock-feeding. (6) Certain impurities are removed through the separator slime.

Development of the centrifugal separator.

The first practical separator of the centrifugal type was invented by Gustaf de Laval, of Sweden, about 1879. The result of his invention led to the hollow bowl machine with continuous inflow for the whole milk and outflow for the cream and skim-milk. While in all the modern separators the principle

of action is the same, there is great variety in the internal devices for aiding the separation of the cream and skim-milk. It may be said there are three chief types about which the others may

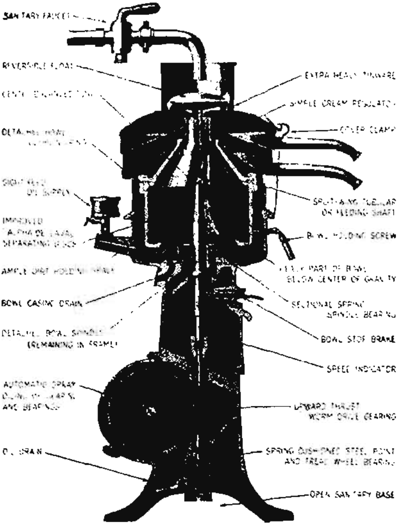


FIG. 45. — De Laval separator, disk-blade type.

be grouped. In the disk machines, of which the De Laval represents the type, the separation is hastened by the milk passing between a series of slanting or cup-shaped disks (see Fig. 45). The second type is represented by the Simplex machine in

which the internal device consists of a series of curved blades which direct the course of the milk in its passage through the bowl (see Fig. 46). A third type is represented by the Sharples tubular (see Fig. 47). In this type, the bowl is of much smaller diameter and much longer than in the other types. The milk enters at the bottom and as it passes up the bowl, which is run at a very high speed, the process of separation takes place. At

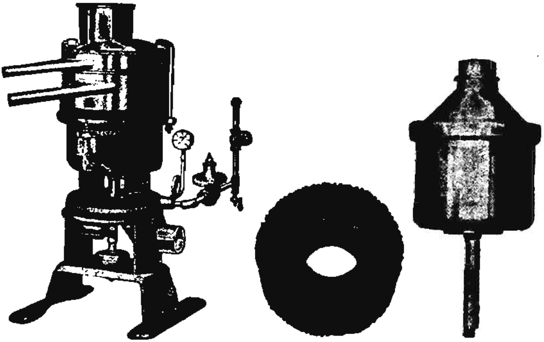


FIG. 46. — Simplex separator, link-blade type

the present time, there are many makes of separators on the market representing a great variety of modifications of the three general types.

Conditions affecting separation.

The completeness of separation and the relative amounts of cream and skim-milk are dependent on the centrifugal force or speed of the bowl, the uniformity of the speed, the temperature of the milk, the rate of inflow, the percentage of fat in the

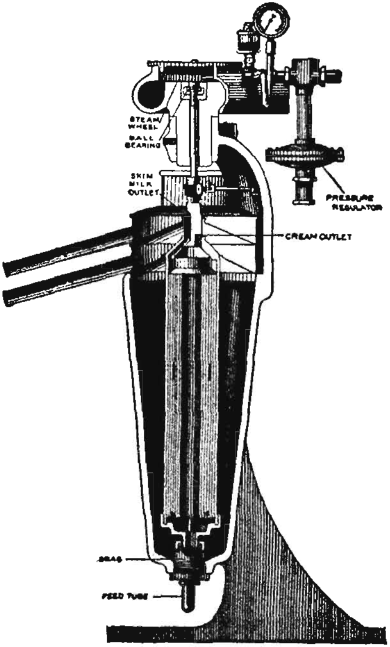


Fig. 47. — Sectional view of Sharples separator, tubular type.

whole milk, the physical condition of the milk, and the position of the cream or skim-milk screw. The centrifugal force exerted upon the particles of milk as they pass through the separator is dependent on the velocity and diameter of the bowl; the greater the speed and the larger the bowl, the greater is the centrifugal force and the more completely will the fat globules be separated from the milk-serum. It is also important that the speed be uniform in order to maintain a constant force upon the milk passing through the bowl. This is illustrated by the following results obtained by Guthrie:[1]

EFFECT OF SPEED ON PERCENTAGE OF FAT IN CREAM AND MILK

Separator	Revolutions of Crank a Minute			
	60		50	
	Cream % fat	Skim-milk % fat	Cream % fat	Skim-milk % fat
No. 1	30.9	.024	21.3	.034
No. 2	28.1	.036	27.6	.041
No. 3	28.8	.054	23.0	.050

The temperature affects the viscosity and fluidity of the milk; the warmer the milk, the less the viscosity and the more easily the particles can move, hence the more complete the separation. Milk is usually separated at temperatures between 85° and 95° F. At lower temperatures, the milk flows more slowly and gives a richer cream and greater loss of fat in the skim-milk. If the temperature is too low, the machine will become clogged and separation will be at least partly prevented, the temperature at which this will take place differing in different styles of machines. The effect of temperature is shown by the following summary of experiments conducted by Guthrie:[2]

[1] C. U. Bul. 360.   [2] C. U. Bul. 360.

EFFECT OF TEMPERATURE ON PERCENTAGE OF FAT IN CREAM AND SKIM-MILK

	90°		80°		75°		70°	
	PERCENTAGE OF FAT IN							
SEPARATOR	CREAM	SKIM-MILK	CREAM	SKIM-MILK	CREAM	SKIM-MILK	CREAM	SKIM-MILK
No. 1 . . .	29.83	.020	36.75	.039	43.12	.069	—	—
No. 2 . . .	28.1	.036	—	—	31.2	.050	39.5	.254
No. 3 . . .	21.0	.031	21.7	.053	—	—	—	—
No. 4 . . .	29.5	.020	—	—	30.9	.024	—	—
No. 5 . . .	28.8	.045	30.2	.052	—	—	—	—

The rate of inflow may affect the completeness of separation and the relation of the cream to the skim-milk by affecting the time in which the milk is passing through the bowl. In the modern machines, however, the rate of inflow is quite accurately regulated by the "float," and if the tank is kept supplied with milk, there will not be enough variation in the rate of inflow to affect appreciably the work of the machine. The percentage of fat in the whole milk has an influence on the percentage of fat in the cream, and also in the skim-milk. The richer the milk, the richer will be the cream and the greater the loss in the skim-milk. In general, the percentage of fat in the cream is proportional to that in the whole milk. In working with one type of separator, Guthrie[1] found that

3 per cent milk gave cream with 23.8 per cent fat;
4 per cent milk gave cream with 31.2 per cent fat; and
5 per cent milk gave cream with 43.4 per cent fat.

At the same time there was a corresponding rise in the fat lost n the skim-milk.

[1] C. U. Bul. 360.

Slight changes in the physical properties of the milk do not have as much effect in centrifugal creaming as in the gravity system. This is due to the fact that the greater force exerted is sufficient to overcome any effect of small fat globules, the presence of fibrin, and other deterrent conditions. This ability of the centrifugal separator to overcome these difficulties makes it far more efficient than the shallow pan, deep setting, and water dilution methods. According to Hunziker,[1] the percentage of fat lost in the skim-milk by the different methods is as follows:

Method	Percentage Fat in Skim-milk
Shallow Pan	0.44
Deep Setting	0.17
Water Dilution	0.68
Centrifugal	0.02

QUALITY OF CREAM FOR BUTTER-MAKING

The quality of butter is dependent on the quality of the cream from which it is made more than on any other factor in connection with its production. While a good butter-maker may be able partly to overcome or disguise defects in the cream, he can never make the highest grade of butter from cream of poor quality. The quality of cream depends on the care it receives from the time the milk leaves the cow until it reaches the vat in the creamery. Whether the farmer delivers whole milk to the creamery or separates it on the farm and delivers only the cream, he should exercise the greatest care in its handling. The milk should be drawn under the same general conditions as those outlined in Chapter VI for the production of market milk. In many sections, it has been found that the farmers who separate the milk at home and deliver cream to the creamery produce a poorer grade than those farmers who

[1] Indiana Bul. 116.

deliver whole milk. There is no good reason for this, since it is easier to give the small volume of cream the proper care than it is the entire quantity of milk.

Directions for care of cream on the farm.

Farrington[1] states the conditions for the production of good cream on the farm as follows:

"1. Place the separator on a firm foundation in a clean, well-ventilated room where it is free from all offensive odors.

"2. Thoroughly clean the separator after each skimming; the bowl should be taken apart and washed, together with all the tinware, every time the separator is used; if allowed to stand for even one hour without cleaning there is danger of contaminating the next lot of cream from the sour bowl. This applies to all kinds of cream separators.

"3. Wash the separator bowl and all tinware with cold water and then with warm water, using a brush to polish the surface and clean out the seams and cracks; finally scald with boiling water, leaving the parts of the bowl and tinware to dry in some place where they will be protected from dust. Do not wipe the bowl and tinware with a cloth or drying towel; heat them so hot with steam or boiling water that wiping is unnecessary.

"4. Rinse the milk-receiving can and separator bowl with a quart or two of hot water just before running milk into the separator.

"5. Cool the cream as it comes from the separator or immediately after, to a temperature near 50 degrees F. and keep it cold until delivered.

"6. Never mix warm and cold cream or sweet and slightly tainted cream.

"7. Provide a covered and clean water tank for holding the cream cans, and change the water frequently in the tank so that the temperature does not rise above 60° F. A satisfactory ar-

[1] Wis. Bul. 129.

rangement may be made by allowing running water to flow through the cream tank to the stock watering tank.

"8. Skim the milk immediately after each milking, as it is more work to save the milk and separate once a day, and less satisfactory, than skimming while the milk is warm, since the milk must be heated again when saved until another milking.

"9. A rich cream testing 35 per cent fat or more is the most satisfactory to both farmer and factory. The best separators will skim a rich cream as efficiently as a thin cream and more skim-milk is left on the farm when a rich cream is sold.

"10. Cream should be perfectly sweet, containing no lumps or clots when sampled and delivered to the haulers or parties buying it."

If the above directions are carefully carried out, the result will be a cream of good clean flavor, smooth texture, and free from foreign matter, undesirable flavors and odors, with a low percentage of acidity.

Grading of cream.

In order to encourage the production of high-grade cream, many progressive creameries are adopting systems of grading cream, the price paid being dependent on the quality. The cream is usually divided into two or three grades and a different price paid for the butter-fat in the different grades. This is a just system, since it pays the farmer for the quality of the product which he delivers, and is the only way by which permanent results can be secured. In those sections of the country in which the farmers deliver their milk or cream direct to the creamery, but little change in quality will take place during transportation, but in sections where the cream must be shipped by train, the loss in quality may be very serious, unless facilities for keeping cream cool during transportation are provided. This is especially important during the hot summer weather. The maintenance of proper temperatures may be provided by

the use of special jackets for the cans or by shipment under ice or in refrigerator cars.

The ripening of cream.

The ripening process covers the changes which take place in cream up to the time that it is placed in the churn, and more particularly its treatment after being received at the creamery. Next to the quality of the fresh cream, the quality of the finished butter is dependent on the ripening process more than on any other factor. The purpose for which cream is ripened is to give the butter the flavor and aroma characteristic of butter of high quality. While the chief purpose of the ripening is to give the proper flavor, it also increases the ease and efficiency of churning. However, butter may be made without the cream being ripened at all, this method being now used to quite an extent in the manufacture of what is known as sweet cream butter, which finds a ready sale in many of our markets.

In the case of most creamery butter, the cream is subjected to the ripening process before churning. This ripening process is the result of the action of certain types of bacteria growing in the cream. The chief change produced is the breaking down of the milk-sugar and the formation of lactic acid by the action of the lactic acid bacteria. While it is not definitely known that all of the changes taking place during the ripening process are the result of the lactic acid bacteria, the desirable changes are very largely associated with this fermentation. The ripening process may be accurately controlled by the use of definite temperatures and by the use of starters. Cream may be ripened naturally by holding at temperatures which favor the desired types of bacteria, but, in the best creamery practice, this method does not control the ripening process with sufficient accuracy. When a starter is used, it may be added to the raw cream or the cream may be pasteurized in order to remove the undesirable bacteria present in it. The preparation and use of starters for butter-making is well discussed by Bouska as follows:

"In practice two kinds of starters are used; the commercial and the natural. The commercial starters are pure cultures of bacteria prepared by bacteriological methods. They are put up in milk, milk-sugar, beef broth, and other substances. Those in the dry form maintain their vitality longer. The milk cultures show their age or ripeness by the coagulation of the milk. They are sold in packages of one to several ounces and are a staple commodity, like yeast. The creameries usually order these cultures to be sent them periodically by mail.

"There are two steps in the preparation of a commercial culture for use in the creamery: The 'building up' and the 'carrying on,' or propagation. Directions for these are sent with the cultures. A great deal has been said and written about *the kind of milk that is best for starters. In the earlier days* many butter-makers preferred milk from fresh cows, or from cows getting good feed. The period of lactation can have only *an indirect and unimportant effect on starters. The fitness of* milk for starters depends upon the number and kind of bacteria that it contains. The fewer the numbers of bacteria, and especially of spores, the better the milk for starters. The presence of a few lactic acid bacteria in milk that is to be pasteurized is not a great defect because they are easily killed by pasteurization. The butter-maker has not the means of knowing what kind of bacteria the milk contains. A bacteriological analysis or a fermentation test would show this, but the results would come so late that they would not be applicable to the lot of milk that has been examined. These methods are of value in finding which patron's milk is best, but the quality of a patron's milk sometimes varies daily. The senses and judgment of the butter-maker are the most practical guides. The sweetest and cleanest milk is the best in the long run.

"A natural starter is derived from a natural fermentation of milk. A very important step in the preparation of such starters is their selection. The most conspicuous characteristic

of a natural starter is the lactic acid fermentation. There is no way for ascertaining immediately whether a given lot of milk will develop a good lactic acid fermentation. It is thought that clean, sweet milk is more likely to produce the desired fermentation. But the lactic acid fermentation itself shows that milk was contaminated with bacteria. This self-same milk is not sweet when the fermentation has progressed far enough to 'turn' the milk.

"The obtaining of a good natural starter depends upon chance as well as judgment. Hence, the best method of selection is to take several small samples of milk, each sample from a different dairy, let them ferment at a temperature that is favorable to the lactic acid fermentation (60°–75° F.), and examine them when they have coagulated. A good lactic fermentation produces a smooth curd free from gas, and there is no wheying off for a long time. Wheying off is usually associated with a bad flavor. The desirable flavor is best learned by experience. It should be acid, pleasant, and clean. A disagreeable odor is an undesirable quality, but often a starter that makes good butter will show a stale or stuffy odor when it is ripened in a closed vessel. Although the logical test of a starter is to ripen cream with it and see what kind of butter it makes, experience soon teaches a butter-maker what starter makes the best butter so that he is soon able to judge a starter simply by sense tests. Having several samples of fermented milk or starters to choose from, the chances of getting a good starter are, of course, much better than where only one sample is taken. The variety affords comparisons and it is easier to judge the quality. When a good starter is found, it can be built up and carried on in the same manner as a commercial starter.

"The relative merits of skim-milk and whole milk for carrying on starters are points of controversy. Theoretically, whole milk is not as good because its fat does not afford any food for the bacteria. It is generally admitted that it is better to select

the milk instead of taking some of the mixed milk. If the benefit of the selection is to be realized, the milk should be skimmed separately and handled in clean utensils. This involves a great deal of extra work. Moreover, the fat in the whole milk does not interfere with the growth of the bacteria. In the cream the bacteria have to grow in the presence of much greater quantities of fat. The fat, however, cloys the sense of taste and makes it somewhat more difficult to judge the quality of the flavor.

"In pasteurizing milk for starters it is best to apply the heat for thirty to sixty minutes. A temperature of 150° F. kills all the sporeless bacteria. Higher temperatures, up to 212° F., do not kill the spores, but they are so weakened by the higher heat that they germinate more slowly and their harmful effect is retarded. This fact, and the results of experience, indicate a *temperature of about 185° to 200° F. as best. The heating and* cooling can be done in cans immersed in water. Stirring hastens the process, but is not necessary when the heating surface is not hotter than about 200° F. Where the heating is done by steam, stirring is necessary to prevent scorching. Starter cans are a great convenience (see Fig. 48).

"The building up of a starter consists in adding a culture to a quantity of pasteurized milk and ripening it. Then it is inoculated into a still larger quantity of milk and so on until the desired amount is obtained. The best results are obtained when the quantity of milk used for a culture is such that it is ripened in forty-eight hours or less; twenty-four hours is still better. When the fermentation has once developed in milk, it grows more vigorously and gives the best results when the ripening period is not over twenty-four hours. When the quantity of milk inoculated is so large that it takes more than twenty-four hours to ripen, the spores that withstood the pasteurization and the bacteria that may accidentally get in have a better chance to develop. Pasteurized milk, if kept long enough, will ferment

and its flavors are usually bad. About one-third to one pint of milk is sufficient for most cultures. Glass jars, enameled ware, china, earthenware, and tin are the best utensils for this purpose.

"The lactic acid bacteria grow the most rapidly at 95° to 108° F. But in impure cultures, like a starter or milk, there are

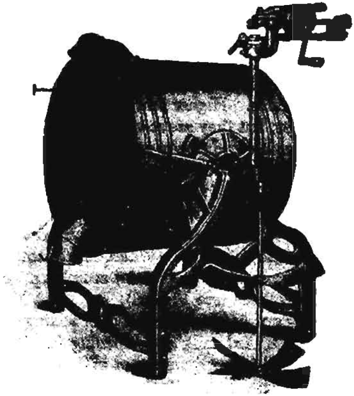


Fig. 48. — Power starter can with water jacket and mechanical stirrer.

bacteria that can compete more successfully with the lactic acid fermentation at high or low temperatures than at mean temperatures. Thus at high temperatures stale flavors and gassy fermentations are frequent, and it is difficult to avoid over-ripening. Bitter and other undesirable flavors are common at low temperatures. It is possible to ripen successfully at 55° to 90°, but the best flavor is developed at 60° to 75° F. It is better to ripen a

culture that has just been inoculated in milk, at higher temperatures, because otherwise the ripening would be too slow.

"When the starter has been built up to the desired quantity it is carried on, or propagated, from day to day. When a ripe starter is to be added to the cream or used for inoculation, it is *best to skim off the top to a depth of about one inch. The top* always has a poorer flavor due perhaps to the contamination from the air and the influence of the air itself especially on the growth of fungi like *Oidium lactis*. These skimmings can be added to the cream and need not be wasted, but their removal before taking some of the starter for an inoculation helps to maintain its good qualities. In this manner the poorer portion is not used for propagation, on the same principle that poor seed corn is discarded. The pasteurized milk is inoculated with such a quantity of the mature starter as will ripen the milk by the time it is to be *used, usually twenty-four hours. An inoculation* of two per cent generally accomplishes this. The length of ripening can also be controlled by the temperature. But ripening at a very high or very low temperature is likely to produce bad flavors. If it is desired to retard the ripening, it is better to lower the temperature a little rather than to reduce the inoculation too much. Reducing the inoculation favors the competing bacteria.

"The quality of a starter should always be examined before it is used for inoculating or before it is added to the cream. At any time it is likely to get so bad that it may do more harm than good, and then it is not worth carrying on. In such a case the maker has to resort to a new culture or a new starter. For this emergency it is well to save out a quart or so of a good starter and keep it cold. A good starter kept at a low temperature will retain its good quality for a week or so. This reserve starter can be built up much more quickly than a commercial culture.

"A starter sometimes gets so bad in a few days that it is not

fit to use; in other cases it remains good for many months. The maintenance of its good quality depends upon the skill of the maker and the bacteriological quality of the milk.

"A starter is in the best condition to use when it contains the greatest number of the desirable bacteria. This occurs about the time that it coagulates. It then contains from five million to two billion bacteria per cubic centimeter. For several days after this the bacteria do not decrease very much and it would not be unfit on this point. If it is kept at a ripening temperature after it has coagulated, bad flavors appear in the course of time. This is called over-ripening. It is not due to an excess of lactic acid, but to the development of other bacteria that produce bad flavors. *Oidium lactis* is also associated with the bacteria in the production of ill flavors. Over-ripening occurs much more slowly at low temperatures. If the starter cannot be used soon after it is ripe, it is best to cool it as low as possible.

"There are conditions where milk is received only every other day. In such cases it has been recommended to make up only a small quantity of starter the first day, save some pasteurized milk, re-pasteurize, and inoculate it the next day. This is hardly necessary. The ripening can be managed so as to take two days or the starter can be allowed to ripen and then cooled. The latter method is best because the combined effect of the low temperature and large amount of lactic acid retards the action of undesirable bacteria. Stirring the starter during ripening keeps the temperature more uniform, but it has little value and is not practiced much. Some stir at the time of coagulation to prevent clotting. Stirring after it has coagulated will not cause wheying off unless the temperature is high or the flavor is bad.

"A starter has the best opportunity for exerting its effect when it is put in the vat before the cream is put in. Some pour the starter into the vat through a strainer to break up the clots of curd which have a tendency to settle to the bottom of the vat.

In practice the butter-makers use from a few per cent to 50 per cent of starter. Less than 2 per cent has very little effect unless the cream is sweet or pasteurized. More than 25 per cent involves the handling of so much material that it is impractical in a large creamery. From 10 to 20 per cent are good amounts for ordinary purposes.

"Adding a large quantity of starter to bad cream and churning immediately improves the flavor of the butter. Washing bad butter in the granular form with a starter also improves it. This method has a great deal of promise. Starters are used in the manufacture of process butter and oleomargarine.

"The commercial starters are likely to give better results in the hands of an unskilled maker. The right kind of bacteria have been selected for him and the rest of the work is more mechanical. A good maker can select a natural starter that is just as good as the best commercial starter. Circumstances sometimes make this difficult or impossible, so that commercial starter has the advantage of uniformity and reliability. However, some commercial starters sometimes fail in quality. Any starter is likely to get bad at any time. Success with all starters depends very much upon the skill and judgment of the maker.

"Buttermilk or cream are sometimes used as starters. They hasten the ripening but they cannot make the product any better than the original cream. They may act as a catch-all for all the taints that come in the cream, and a trouble occurring in one day's cream is likely to be carried from day to day. There is no chance of improvement above the general average.

"The advantages and disadvantages of using starters in butter-making were under discussion for a long time. To-day practically all butter-makers appreciate their value and almost all the large creameries use them. It is an open question whether it would pay to use a starter in making butter on a small farm. In such a case, the value of the time it takes to prepare a starter is too great in proportion to the total value of the butter."

Amount of starter to use. — The amount of starter which should be used with any given lot of cream will vary with the age of the cream, the percentage of fat, and the time during which the ripening process is to take place. The fresher the cream is when the starter is added, the greater the opportunity to control the ripening process, due to the fact that lactic acid bacteria soon develop sufficiently to hold in check the growth of the undesirable species which may be present. Also the fresher and sweeter the cream, the smaller the per cent of starter needed. On the other hand, if the cream is old and partly ripened, a larger per cent may be desirable. Under some conditions, as low as 2 per cent of starter may be used in sweet or pasteurized cream, but under ordinary conditions, from 10 to 20 per cent will give good results. If higher percentages than this are used, it involves considerable labor in the preparation of the starter and a larger percentage of buttermilk to handle and the loss of fat in churning may also be increased. If the butter-maker knows the quality of his cream and the length of time during which the ripening process should take place, he can judge very accurately the amount of starter which should be used.

Quality of starter. — It is of the greatest importance that the starter used should be of the best possible quality. While it is not absolutely necessary that the starter should be a pure culture, the more nearly pure it is, the better the results which will be obtained. It is also necessary that the bacteria be in an active, vigorous condition in order that they may develop rapidly in the cream. There are many strains of the lactic acid producing organisms, and some strains give better results than others, especially in the flavor of the butter. The commercial cultures which are on the market contain strains which have been carefully tested and can be relied on to give satisfactory results if they are properly prepared. In the preparation of the starter, it is of the greatest importance that the skim-

milk should be thoroughly sterilized. In creameries where large quantities of cream are handled, the amount of starter needed is quite large, and a starter can be made most satisfactorily in the starter cans made especially for the purpose. These cans are so constructed that the skimmed milk can be sterilized in them, then cooled to the proper temperature, the mother starter added, and the desired temperature for development maintained. In the use of starter, care should be taken to see that it has developed to the point at which the bacteria have their greatest activity, which condition exists just after the starter has become completely coagulated; if it is too old, the bacteria are weakened by the presence of the lactic acid. An over-ripe starter does not give satisfactory results in cream ripening, and should not be used.

The butter-maker cannot give too much attention to the quality of his starter, for while a good one is of material aid in producing butter of uniformly good quality day by day, the use of a poor one will just as surely result in injuring the quality of the product.

Temperature for ripening cream. — The bacteria which produce lactic acid grow most rapidly at temperatures of about 80° to 95° F. Other species which produce undesirable changes in the cream also grow rapidly at this temperature. The object sought in the ripening process is the greatest development of the acid-producing organisms relative to the other species which may be present in the cream. It has been found that this result is best obtained by ripening the cream at temperatures from 60° to 70° F. The acid bacteria will develop at temperatures below 60°, but their growth is much slower both actually and relatively compared with certain other species which are not desirable. Under certain conditions it may be desirable for the butter-maker to use temperatures higher or lower than the above, but under normal conditions, the use of these temperatures will give the greatest relative develop-

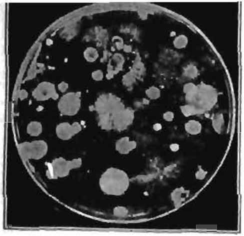
ment of the lactic acid bacteria and produce butter of the best quality.

Amount of acid to develop. — The amount of acid to be developed in the cream, and the degree of acidity which cream should have at the close of the ripening period, will depend both on the quality of the cream and the type of butter desired by the consumer. Some markets require more highly flavored butter than others, but all the markets require that the flavor should be uniform from day to day. This necessitates careful control of the acid fermentation and the churning of cream with a uniform acidity. While the butter-maker may be able to change with some accuracy the amount of acidity in the cream, judging from its appearance, taste, and odor, it is not wise to depend on the senses. Several methods for accurately determining the acidity are in common use, and one of these should be employed by the butter-maker.

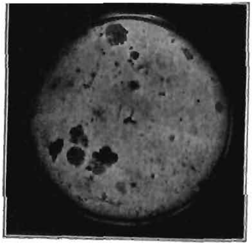
PASTEURIZATION OF CREAM FOR BUTTER-MAKING

(See Plate XIII)

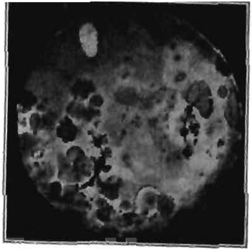
The pasteurization of cream for butter-making is done for two purposes. (1) It enables the butter-maker to eliminate the miscellaneous microörganisms in the raw cream, and thus more completely control the nature of the fermentation by the use of starter. In this way it is possible to secure a more uniform product. Whether or not the quality of the butter is improved by the pasteurizing process will depend largely on the quality of the raw cream. If the cream is of poor quality, the flavor of the butter will be improved, while this will probably not be the case if high-grade sweet cream is used. (2) The pasteurization, if properly done, will eliminate disease-producing bacteria, and in this way protect the health of the consumer from certain diseases, the organisms causing which might be carried in the butter.



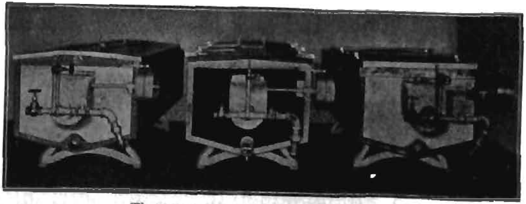
Colonies of bacteria and molds from dust in stable air.



Colonies of bacteria and molds falling from cow's udder during 15 seconds.



Colonies of bacteria and molds from cow hairs.



Three types of pasteurizers and ripeners.

PLATE XIII.

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Two methods are in common use for pasteurization of cream for butter-making. These are the "flash" method, in which a high temperature (180° to 185° F.) is used, and the cream immediately cooled down, and the "holding" or "vat" method, in which a lower temperature is used, from 140° to 145° F., and maintained for twenty to thirty minutes, after which the cream is cooled. The experimental work conducted on the pasteurization of cream for butter-making has not given entirely uniform results. The general results obtained by the different methods are summarized by Mortensen[1] as follows:

"1. Pasteurization of either sweet or sour cream improves the flavor of the resulting butter.

"2. Vat pasteurization seems to be the most efficient method of sour cream pasteurization for improvement of flavor.

"3. The per cent of butter-fat lost in the buttermilk when churning raw cream is slightly greater than with cream pasteurized while sweet. Reversed results were obtained when sour cream was pasteurized.

"4. The per cent of butter-fat lost in the buttermilk when churning cream pasteurized while sour by the holding method is greater than when churning cream pasteurized while sour by the flash method.

"5. The body of the resulting butter is slightly injured by pasteurizing sweet cream by the holding method.

"6. Butter manufactured from raw cream has higher moisture content than butter manufactured from cream pasteurized by the flash method.

"7. Prolonged heating of sour cream produces a higher moisture-content in the resulting butter.

"8. The per cent protein content of the resulting butter is not influenced by the pasteurization of sweet cream, but is decreased by pasteurization of sour cream."

[1] Iowa Bulletin No. 156, page 15.

CHURNING

(See Fig. 49 and Plate XIV)

Churning is the process of separating the butter-fat from the other constituents in the cream. This is brought about by subjecting the cream to violent agitation in such a way that the butter-fat globules are brought together and cohere as a result of concussion. This gathering together of the fat globules into butter granules is influenced by a number of factors, including the richness of the cream, the temperature, the ripeness of the cream, the viscosity of the cream, the amount of cream in the churn, the nature of the agitation, the size and quality of the fat globules.

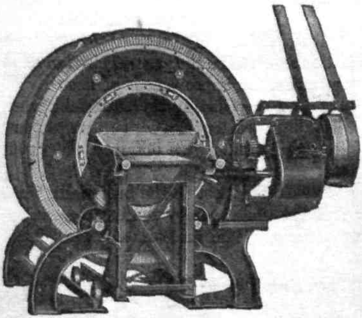
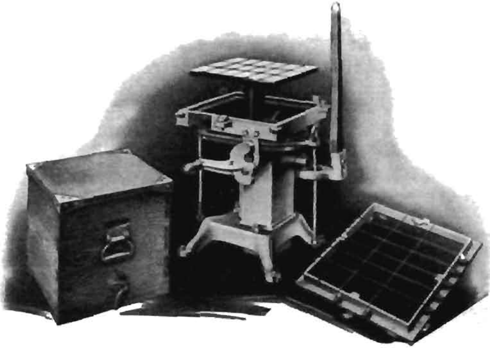


FIG. 49. — Simplex churn and butter-worker.

Richness of the cream.

The fat globules exist in the cream in enormous numbers, and the richer the cream, the more closely the fat globules come into contact with each other. For this reason, rich cream churns more easily than thin cream, other things being equal. It, however, should not be so rich as to adhere to the sides of the churn and prevent its receiving the proper amount of agitation as the churn is revolved. Under ordinary conditions cream con-



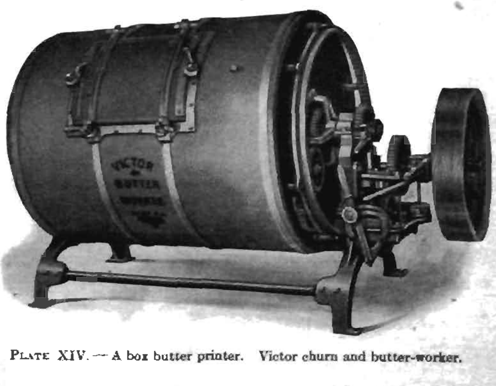


PLATE XIV. — A box butter printer. Victor churn and butter-worker.

taining 30 to 45 per cent of butter-fat is the most satisfactory for churning.

Temperature of cream.

The temperature of the cream is one of the most important factors in determining its churnability. Other things being equal, the higher the temperature, the sooner the churning process will be completed; however, it should always be well below the melting point of the butter-fat. If the temperature is too high, the fat globules may be broken up, resulting in butter with a greasy texture. Too much buttermilk may also be incorporated in the butter. On the other hand, if the churning temperature is too low, the cream becomes more viscous and the churning process is more difficult; also if the temperature is sufficiently low, the cream may adhere to the sides of the churn and thus escape receiving sufficient agitation to accomplish the churning process. The temperature is of great importance in determining the quality of finished butter, and will vary decidedly under different conditions. Such a temperature should be used as will allow the fat globules to unite easily into the form of small masses or granules. Any conditions which tend to make the churning process more difficult call for the use of higher temperatures, while any conditions which favor the coalescence of the fat globules should be accompanied by lower temperatures. The proper temperatures to be used under any given conditions must be determined by the butter-maker, based on his knowledge of the existing conditions. Under ordinary conditions, the proper churning temperature will be between 50° and 65° F.

The ripeness of the cream.

The ripeness of the cream affects its ease of churning. This is due to the fact that the development of the lactic acid lessens the viscosity of the cream, hence ripe or sour cream will churn more easily than sweet cream. If thin cream is allowed to become over-ripe, the casein will become coagulated and may

be incorporated in the butter. The churning process should then be stopped while the butter granules are still small, and the coagulated particles of casein can be removed by the use of wash water. The final composition of the butter is not affected by the ripeness or acidity of the cream.

The amount of cream in the churn.

The fullness of the churn affects the amount of agitation which the cream receives as the churn revolves. Should the churn be too full, there will be little opportunity for the cream to fall, hence little agitation and concussion of the fat globules. On the other hand, if too small an amount of cream is in the churn, it may adhere to the side walls and receive little or no agitation. Therefore, the amount of cream in the churn should be such as to give the greatest degree of agitation to the cream during the churning process. When a small amount of cream is used, it is more difficult to control the temperature, and especially in cold weather it may be lowered to such an extent that the churning process may be delayed. Best results will usually be obtained if the churn is from one-third to one-half full of cream. With this amount, other conditions being correct, the churning process should take place in approximately twenty-five minutes.

The speed of the churn.

The speed at which the churn is revolved has a marked effect on the ease of churning and should be such as to give the greatest degree of agitation to the particles of cream. Should it be too rapid, the centrifugal force will hold the cream against the inner surface of the churn and it will simply revolve with the churn and receive very little agitation. If, on the other hand, the churn is revolved too slowly, the cream will lie in the bottom of the drum with but little agitation instead of being carried up on the sides of the churn, from which it falls off before it reaches the top. The proper speed varies with the construction of the churn, and no definite directions can be given. The

internal structure of the churn is also an important factor. In some cases, the churn consists simply of a hollow drum, while in others flange boards are placed in such a way as to assist in raising the cream at the side and allowing it to fall into the main body of the cream at the bottom of the churn.

The quality of the fat globules.

The ease with which cream may be churned is affected by both the size and the quality of the fat globules. As has already been stated (Chapter IV), the character of the fat globules is influenced by the breed and individuality of the cows, the period of lactation, and the nature of their feed. Conditions which result in large-sized fat globules and an increased proportion of soft fats assist in the churning process, while the presence of large numbers of small fat globules, and an increase in the hard fats, make the churning more difficult.

It will be seen from the above that the churnability is influenced by many factors, and the expert butter-maker must bear in mind all of these factors in determining the treatment which his cream shall receive. While all of the above factors influence the ease in churning, the most important ones are the percentage of fat in cream, temperature, the fullness of the churn, and the speed at which it is revolved. If these factors can be properly controlled, there should be little difficulty in churning normal cream. These factors should be so controlled that the churning process will take place in twenty-five to thirty minutes, giving firm granules of the desired size.

When to stop the churn.

It is important that the churning process should be stopped at the right point. The two things to be especially controlled are the completeness of the churning and the removal of the buttermilk. It is customary to stop the churn when the butter granules appear in the buttermilk, and are somewhat larger than kernels of wheat and about the size of small peas, all the butter-fat in the cream having been collected in these small

butter granules (see Plate III, p. 122). When this stage has been reached, the buttermilk will lose its creamy appearance and appear as a watery bluish liquid. The smaller the butter granules, the more easily the buttermilk can be removed in the washing process. If the churning is continued until the butter granules are too large, the buttermilk will be incorporated in them, and cannot be washed out. The purpose of the butter-maker is to stop the churning process at an intermediate point which will give the best net result.

Difficult churning.

Sometimes great difficulty is experienced in the churning process, more frequently in the case of butter-making on the farm, but also sometimes in the creamery. The greatest difficulty is usually experienced in the fall and early winter when the cows are in an advanced stage of lactation and are receiving dry feeds of such a nature as to produce hard butter-fat. In creameries, this difficulty can easily be overcome by the proper ripening of the cream and modification of churning conditions. In extreme cases, it may be desirable to modify the nature of the feed which the cows are eating in order to soften the butter-fat.

WASHING THE BUTTER

As soon as the churning has been completed, the buttermilk should be drawn off from the bottom of the churn into a fine-meshed strainer in order to prevent the loss of the small particles of butter. The butter should then be washed with clean pure water.

Purpose of washing.

The purpose of washing the butter is to remove the buttermilk and under some conditions modify the hardness or softness of the butter-fat. As soon as the buttermilk has been removed, an amount of water about equal to the amount of buttermilk

which has been removed should be added, the churn should then be revolved a few times at a moderate speed and this water drawn off, repeating this process once or twice until the water, as it drains off the butter, is quite clear, having very little appearance of milkiness.

Temperature of the water.

In general, the temperature of the water used for washing should be very close to the temperature of the butter-fat, but it is frequently desirable to raise or lower the temperature in order to modify the texture of the fat. If the butter is softer than is desired, water a few degrees colder can be added and allowed to stand until the butter-fat has gained the temperature of the water, and if the fat is too hard at the close of the churning process, it can be softened by using water a few degrees warmer than the temperature of the fat. Under ordinary conditions, the water should not vary materially from between 50° F. and 55° F. It should be borne in mind that too sudden changes in the temperature of the butter-fat injure its texture and, therefore, the quality of the finished butter.

Quality of wash water.

It is very important that the water used for washing should be as pure as possible. Water from unknown sources should not be used, or from wells or springs which are subject to contamination, since the bacteria in the water may be left in the butter, injuring both its keeping quality and its flavor. If the water supply is not pure, it should be purified either by an efficient process of filtering or by boiling, but either of these methods is more or less expensive, and a pure natural supply should be available for washing butter.

SALTING THE BUTTER

After the wash water has been drawn off, the butter should be salted to meet the requirements of the trade. The amount

of salt may vary from 0 up to 4 per cent or 5 per cent. As the chief purpose of salting is to improve the flavor of the butter, the amount of salt to be added will depend on the requirements of the market. At the present time, there is a strong demand for unsalted butter. The use of salt tends to cover up undesirable flavors in butter and thus hide the effects of poor cream; also it is believed by some that salt improves the keeping quality of the poorer grades of butter. When pure cream is used for butter-making, a high percentage of salt is usually added. The salt is usually applied by sifting it over the butter while it is in the granular form in the churn, and if a high grade of salt is used, it very quickly becomes completely dissolved and subsequent working incorporates it uniformly through the butter. Probably the salt is not taken up by the butter-fat, but remains in solution in the moisture which is incorporated in the butter; the amount of moisture in the butter, therefore, will influence the amount of salt which can be incorporated. Nothing but the best quality of salt should be used because of the danger of its not becoming fully dissolved and the condition known as gritty butter resulting. This condition may be due either to using salt of poor quality or in such great quantity that it cannot be dissolved in the water which remains in the butter. If the salt is not completely dissolved, it will give the butter a mottled appearance, which may be due to other causes, but usually is the result of the uneven distribution of salt.

MOISTURE-CONTENT OF THE BUTTER

The moisture-content of the butter is more variable than any other constituent. The percentage of water in the finished butter may vary between rather wide limits without affecting its commercial value. While there is no direct relation between the moisture-content and the quality of the butter, it is important from the commercial standpoint that this factor be con-

trolled with considerable accuracy, which can be done by modifying the methods of manufacture. A variation of 2 or 3 per cent in moisture-content means a large difference in the money returns to the creamery. The butter-maker should be sure that the moisture-content of his product does not exceed the legal limit of 16 per cent as established by the National Government. The nearer he can approach to this limit without danger of going over it, the greater will be his yield. The moisture-content should be controlled by the frequent use of an accurate moisture test. There are, however, certain factors which are not within the control of the butter-maker. Hunziker[1] summarizes the factors affecting the control of moisture as follows:

The factors under the control of the butter-maker (Hunziker).

1. The property of butter to mix with and hold moisture is largely controlled by its mechanical firmness or texture. Soft butter mixes with and holds moisture more readily than firm and hard butter.

2. Aside from the process of manufacture the mechanical firmness of butter is governed by the chemical composition of the butter-fat and the size of the fat globules.

3. The olein content of butter-fat is the most dominant factor in the determination of the mechanical firmness of butter. Generally speaking, the softness of the butter increases or decreases as the per cent olein increases or decreases.

4. The per cent volatile acids may also influence the mechanical firmness of butter, but its effect is usually offset by more potent influences of other facts which operate simultaneously but in the opposite direction.

5. The melting point is not a correct index of the mechanical firmness of butter.

6. The melting point of butter-fat is influenced by the

[1] Ind. Buls. 159 and 160.

volatile acids and olein. It is controlled by the relative proportion of the individual fatty acids.

7. The chemical composition of butter-fat is largely controlled by breed, period of lactation, and feed.

8. The butter-fat from Ayrshires and Holsteins contains less volatile acids and more olein and makes a softer butter than that from the Jerseys.

9. At the beginning of the period of lactation the volatile acids are highest and the olein lowest. As the period of lactation advances, the volatile acids decrease and the olein increases.

10. The feed is the most dominant factor controlling the chemical composition of the butter-fat.

11. Feeds rich in vegetable oils, also blue-grass pasture, produce butter-fat relatively high in olein, low in volatile acids, and make a soft butter. Feeds rich in starches and sugars and poor in vegetable oils, also dry hay, tend to increase the volatile acids, decrease the olein, and produce a relatively firm butter.

12. The size of the fat globules also affects the mechanical firmness and moisture-content of butter. Other conditions being equal, cream with large average globules makes a softer butter which retains more water than cream with small average globules.

13. The size of the fat globules is controlled largely by breed, period of lactation, and by changes of feed and other factors affecting the physical condition of the animal.

14. The Channel Island breeds produce milk with much larger fat globules than the Ayrshires and Holsteins. Milk from fresh cows contains larger fat globules than milk from cows well advanced in their period of lactation. Abrupt changes of feed temporarily increase the average size of the fat globules.

Factors not under the control of the butter-maker (Hunziker).

1. The richness and acidity of the cream, size of the butter granules, temperature of and churning in wash water, method

of salting and amount of salt used, do not materially influence the moisture-content of the finished butter.

2. Large churnings yield butter with a higher per cent of moisture than small churnings. Butter from raw cream contains more moisture than butter from pasteurized cream. High churning temperatures make butter retain more moisture than low churning temperatures. Working the butter in water regardless of temperature increases the moisture-content of butter.

3. The secret of moisture control lies in regulating the churning temperature and in adjusting the amount of water present during the working process according to the firmness of the butter as determined by the chemical, physical, and mechanical properties of the butter-fat and in the systematic use of a reliable moisture test.

4. Conditions that cause the formation of round, smooth butter granules, such as very thin cream held at a low temperature for a long time and which requires excessive churning and tends towards salviness of the butter, make moisture control more difficult and the results more uncertain than when the butter granules are irregular, flaky, and not too firm.

5. The moisture is not evenly distributed throughout the churn. For this reason it is not safe to run too close to the 16 per cent limit, and it is advisable to establish 15 per cent as the danger line.

6. In order to secure a representative sample of the butter in churn, it is necessary to take small portions of butter from all parts of the churn. When sampling, care should be taken to avoid water pockets.

7. Some moisture is lost during the transfer of the butter from the churn to the tub or box and when printing the butter. This loss tends to be greater during the winter months when the butter is firm than during the summer months when the butter is soft. A conservative estimate puts the average loss of moisture in packing at about 5 per cent.

8. Considerable moisture is lost during the storage of butter. This loss is controlled by the salt content of the butter and by the thoroughness of moisture incorporation. Unsalted butter loses very little, if any, moisture in storage. The more salt the butter contains, the greater is the loss of moisture in storage. Butter in which the moisture is properly incorporated loses less moisture than butter with a loose and leaky body.

9. The accuracy of the results of moisture determinations by the butter-maker depends on the preparation of the sample, the sensitiveness, condition, and manipulation of the balance, and the carefulness and judgment of the operator in making the test. Most of the moisture tests now available for the use of the butter-maker are satisfactory and yield reasonably accurate results if manipulated according to directions.

WORKING THE BUTTER

After the butter has been washed and the salt evenly distributed over the granular mass, it should be carefully worked. The purpose of working is threefold: (1), thoroughly to incorporate the salt through the butter; (2), to remove any excess of buttermilk or water; and (3), to give the butter a compact, close-textured, firm body. The amount of working necessary to accomplish these objects will depend on the conditions. If the butter granules are rather small and the salt has been evenly distributed, less working will be required than if the butter is in larger lumps. The temperature and hardness of the butter-fat and the quality of the salt will affect the time required for its going completely into solution, which is very important in order to prevent the butter showing a mottled appearance after it is printed or packed. The amount of working will affect the body of the finished product; for, while it is important that the butter should be worked sufficiently to give it a firm, even body, over-working will break down the body and give a

greasy, salvy texture. The texture of the finished butter should resemble the granular structure of a piece of broken steel. If it has been properly made, no special effort will be needed to remove an excess of buttermilk or moisture, but the amount of moisture remaining in the butter can be materially influenced by the amount and nature of the working. The percentage of water in the finished butter may vary considerably without affecting its commercial quality, but care should be taken that the moisture does not exceed the legal limit of 16 per cent as established by the National Government. The butter-maker should control both the percentage of moisture and of salt in his product by making careful tests during the finishing process and just before the butter is printed or packed.

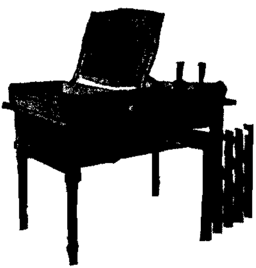


FIG. 50 — The "Acme" butter-printer. See also Plate XIV, p. 249.

PRINTING AND PACKING THE BUTTER

(See Fig. 50 and Plate XIV)

The form in which the butter is finished will depend on the market. The present tendency is toward the use of one-pound prints in preference to tubs, especially when made for immediate use; but if it is to be put into cold storage, it is usually packed in tubs. When the butter is to be put into the form of prints, it should be handled at such a temperature as not to affect its body, but at the same time to admit of easy handling. In printing, care should be taken to have the butter well pressed

into the printer that there may be no air spaces left to detract from its appearance or to cause under-weight. A finished print should have straight, clean-cut surfaces and without finger or ladle prints; it should then be wrapped in a good quality of parchment paper to prevent contamination and the loss of moisture by evaporation. Usually the wrapped prints are then placed in pasteboard cartons and these packed in boxes.

In case the butter is packed in tubs, the best quality of ash tubs should be used. These are made in special sizes, the one most commonly used holding from sixty to sixty-three pounds of butter. They should be clean and dry and free from mold. Many creameries are now coating the inside of the tubs with hot paraffin in order to prevent the growth of mold and the loss of moisture from the butter. Several paraffin devices are now in use which spray the inside of the tub evenly with hot paraffin which soaks into the pores of the wood, making it impervious to moisture and forming surfaces on which molds do not grow.

The butter tub should be lined with a good quality of parchment paper, using a circle in the bottom, and also on the surface of the finished package. When the tub is filled, it should present a smooth, even surface with an inch of the side liner pressed smoothly against the surface of the butter. A parchment circle should then be placed over the top and pressed down firmly against the butter. The appearance of the finished package, and especially the top of the butter, is an important factor in its market value.

BUTTER GRADES AND SCORES

The butter markets recognize definite grades of butter and standards of scoring. The classification and grades established by the New York Mercantile Exchange will illustrate the methods in use.

BUTTER RULES

OF THE

NEW YORK MERCANTILE EXCHANGE

May, 1916

CLASSIFICATIONS — Grades and Scores

1. Butter shall be classified as Creamery, Renovated, Ladles, Packing Stock, and Grease Butter.

Definitions

2. *Creamery.* — Butter offered under this classification shall have been made in a creamery from cream separated at the creamery or gathered from farmers.

3. *Renovated.* — Butter offered under this classification shall be such as is made by melting butter, clarifying the fat therefrom and rechurning the same with fresh milk, cream or skim-milk, or other similar process.

4. *Ladles.* — Butter offered under this classification shall be such as is collected in rolls, lumps, or in whole packages and reworked by the dealer or shipper.

5. *Packing Stock.* — Butter offered under this classification shall be original farm made butter in rolls, lumps or otherwise, without additional moisture or salt.

6. *Grease Butter* shall comprise all classes of butter grading below thirds, or of packing stock grading below No. 3 as hereinafter specified, free from adulteration.

GRADES

7. Creamery, Renovated and Ladles shall be graded as Extras, Firsts, Seconds and Thirds; and Packing Stock shall be graded as No. 1, No. 2 and No. 3.

Definition of Grades

8. Grades of Salted Butter must conform to the following requirements.

EXTRAS

9. Shall be a standard grade of average fancy quality in the season when offered under the various classifications. Ninety per cent shall conform to the following standard; the balance shall not grade below FIRSTS:

Flavor. — Must be sweet, fresh and clean for the season when offered if Creamery, or sweet, fresh and reasonably clean if Renovated or Ladles.

Body. — Must be firm and uniform.

Color. — Not higher than natural grass, nor lighter than light straw, but should not be streaked or mottled.

Salt. — Medium salted.

Package. — Sound, good, uniform and clean.

FIRSTS

10. Shall be a grade next below EXTRAS and must be good butter for the season when made and offered, under the various classifications. Ninety per cent shall conform to the following standard; the balance shall not grade below SECONDS.

Flavor. — Must be reasonably sweet, reasonably clean and fresh if Creamery or Renovated, and reasonably sweet if Ladles.

Body. — Must be firm and fairly uniform.

Color. — Reasonably uniform, neither very high nor very light.

Salt. — May be reasonably high, light or medium.

Package. — Sound, good, uniform and clean.

SECONDS

11. Shall be a grade next below FIRSTS.

Flavor. — Must be reasonably good.

Body. — If Creamery, must be solid boring. If Ladles or Renovated, must be 90 per cent solid boring.

Color. — Fairly uniform, but may be mottled.

Salt. — May be high, medium or light.

Package. — Good and uniform.

THIRDS

12. Shall be a grade below SECONDS and may consist of promiscuous lots.

Flavor. — May be off flavored and strong on tops and sides.

Body. — Not required to draw a full trier.

Color. — May be irregular or mottled.

Salt. — High, light or irregular.
Package. Any kind of package mentioned at time of sale.
13. (For grades higher than EXTRAS see paragraph No. 29.)

No. 1 PACKING STOCK

14. Shall be sweet and sound, packed in large, new or good uniform second-hand barrels, having a wooden head in each end, or in new tubs, either to be parchment paper lined. Barrels and tubs to be packed full.

No. 2 PACKING STOCK

15. Shall be reasonably sweet and sound, and may be packed in promiscuous or different kinds of barrels, tubs or tierces, without being parchment paper lined, and may be packed in either two-headed or cloth-covered barrels.

No. 3 PACKING STOCK

16. Shall be a grade below No. 2, and may be off-flavored, or strong; may be packed in any kind or kinds of packages.
17. Charges for inspection of Packing Stock shall be the same as the rules call for on other grades.
18. *Mold.* — There shall be no grade for butter that shows mold.

KNOWN MARKS

19. Known marks shall comprise such butter as is known to the trade under some particular mark or designation and must grade as EXTRAS or better if Creamery or Renovated, and as FIRSTS or better if Ladles in the season when offered unless otherwise specified. Known marks to be offered under the call must previously have been registered in a book kept by the Superintendent for that purpose. If Renovated, the factory district number and state must be registered.

SCORING

20. *Scoring.* — The standard official score shall be as follows and shall apply to Salted Creamery Butter only.

Flavor	45 points
Body	25 points
Color	15 points
Salt	10 points
Style	5 points
	100 points

21. Extra Creamery may score either 91, 92 or 93 points at the discretion of the Butter Committee, who shall determine the required score from time to time in such manner that it shall represent an average fancy quality in the season when offered. But butter scoring more than required for EXTRAS shall be deliverable on a contract for EXTRAS, and may be branded as such at the request of seller, or buyer. Any change in the Standard score required for EXTRAS shall, after authorization by the Butter Committee, be announced by the caller at the opening of the next regular call and posted upon the bulletin board of the Exchange and be effective 24 hours later.

22. The minimum score of FIRSTS shall, at all times, be 4 points below the score required for EXTRAS.

23. The minimum score of SECONDS shall be 5 points below the minimum score required for FIRSTS.

24. The minimum score of THIRDS shall be 7 points below the minimum score required for SECONDS.

UNSALTED CREAMERY

EXTRAS

25. Shall be a standard grade of average fancy quality in the season when offered under the various classifications. Ninety per cent shall conform to the following standard; the balance shall not grade below FIRSTS.

Flavor. — Must be sweet, fresh and clean for the season when offered.

Body. — Must be firm and uniform.

Color. — May be very light straw, white, or natural grass, but must not be streaked or mottled. The seller must specify the color at time of sale.

Package. — New, uniform and clean.

FIRSTS

26. Shall be a grade next below EXTRAS and must be good butter for the season when made and offered, under the various classifications. Ninety per cent shall conform to the following standard; the balance shall not grade below SECONDS.

Flavor. — Must be reasonably sweet, reasonably clean and fresh.

Body. — Must be firm and fairly uniform.

Color. — May be very light straw, white, or natural grass, but must not be streaked or mottled. The seller must specify the color at time of sale.

Package. — Sound, good, uniform and clean.

SECONDS

27. Shall be a grade next below FIRSTS.
Flavor. — Must be reasonably good.
Body. — Must be solid boring.
Color. — Fairly uniform, but may be mottled.
Package. — Good and uniform.

THIRDS

28. Shall be a grade below SECONDS and may consist of promiscuous lots.
Flavor. May be off flavored and strong on tops and sides.
Body. — Not required to draw a full trier.
Color. — May be irregular or mottled.
Package. — Any kind of package mentioned at time of sale.

The common defects which are found in butter, together with their causes and methods for prevention, are summarized by Michels [1] as follows:

BUTTER DEFECTS AND HOW TO CORRECT THEM

The following pages of this bulletin, written by *Michels*, are intended as a ready reference that will aid the butter and cheese-maker in locating the most common defects found in butter and cheese, their probable cause and a remedy that may be applied.

A DEFINITION OF GOOD BUTTER

FLAVOR, should be rich, pleasing, creamy and suggest nothing objectionable to either the taste or smell.
BODY, should be firm and waxy.
COLOR, should be even, showing a luster and an oat straw shade unless tbe particular market wants a different color.
SALT, well dissolved and just enough to bring out the highest flavor of the butter.
PACKAGE, clean and neat in appearance.

BUTTER FLAVOR DEFECTS

I. CURDY FLAVORS: Indicated by a sour cottage cheese smell and taste.

[1] Wisconsin Bulletin, No. 182.

Causes:
1. Adding wheyed-off starters to the cream.
2. Adding an over-ripe starter while the cream is at too high a temperature.
3. Ripening a very thin cream at a high temperature.

Remedies:
1. Do not use a starter that shows whey on top.
2. Never add a high ripened starter until the cream is cooled down to 65 degrees F.
3. Cream should test 30 per cent or more butter-fat, a lower testing cream should not be ripened much above 60 degrees F.

II. HIGH ACID FLAVORS: Indicated by an excessive sour smell and taste.

Causes:
1. Over-ripening of the cream before churning.
2. The use of an over-ripe starter.
3. Receiving part of the cream in an over-ripe condition.

Remedies:
1. Develop less acid in the cream before churning.
2. Do not use a starter having over 0.70 per cent acid.
3. Cream containing over 0.50 per cent of acid should not be mixed with sweeter cream, but churned separately.

III. LACKING FLAVOR: Lacking taste and smell.

Causes:
1. Churning the cream too sweet.
2. Too much washing of the butter granules.
3. By using a dead or inactive starter.

Remedies:
1. Cream should not contain less than 0.45 per cent of acid, even when a light flavored butter is wanted.
2. When butter is churned at low temperatures, one washing or rinsing is sufficient.
3. Never use a newly prepared starter until it sours readily.

IV. RANCID OR OLD CREAM FLAVORS: Smells and tastes like old cream or old butter.

Causes:
1. Over-ripening the cream.
2. Holding the ripening cream too long before churning.
3. Ripening the cream at very high temperatures.
4. Holding some of the cream or milk too long before churning.
5. Keeping the butter at too high a temperature after churning.

Remedies: 1. When cream is kept over night to be churned the next morning, it should not contain more than .55 per cent of acid.
2. Cream should not be cooled down after ripening with the idea that it will keep its fine, creamy, acid flavor until churned several hours later.
3. Start ripening the cream below 68 degrees F.
4. Old or over-ripe cream or milk should not be mixed with sweet cream, but churned separately. Milk or cream, even under the most favorable conditions, should not be kept longer than two days.
5. After churning, keep the butter in the refrigerator at a temperature of 50 degrees or below.

V. Oily or Greasy Flavors: Indicated by an oily and greasy taste and smell.

Causes: 1. Holding the milk or cream at too high a temperature before delivering to the creamery.
2. Ripening, churning, and working when at too high a temperature.
3. Using a poor grade or too much butter color.

Remedies: 1. Hand-separator cream should be cooled to 60 degrees within an hour after separating.
2. Do not ripen the cream above 65 degrees F. Churn and work at low enough temperature so that one washing of the granules will take out all of the buttermilk; it will then be in such condition that the butter will not turn greasy while being worked.
3. Never use bad smelling color or one that has a sediment at the bottom; use no more color than is necessary to satisfy your trade.

VI. Fishy Flavors: Indicated by a bad taste and fishy smell.

Causes: 1. Uncleanliness in handling the cream and milk at the farm.
2. Leaky cream or milk vats at the creamery.
3. May be produced by certain species of bacteria.

Remedies: 1. Keep separators, pails, cans and tanks for cooling clean at all times.
2. Never use a leaky vat, dipper or can for handling milk or cream.
3. If produced by certain species of bacteria it is certain that they grow in dirt, hence cleanliness is necessary.

VII. STABLE FLAVORS: A bad taste and cow stable smell.

Causes: 1. Uncleanliness in milking.
2. Keeping the cream or milk in or near a dirty cow stable.

Remedies: 1. See that the stable and cows are clean before milking and milk with clean, dry hands.
2. All milk should be removed from the stable as soon as milking is finished. Never keep the milk or cream near the stable or manure piles.

VIII. BITTER FLAVORS: Indicated by a bitter taste.

Causes: 1. Holding cream too long a time at low temperature before churning.
2. May develop in the starter.
3. Bacteria brushed from the cow's udder while milking.

Remedies: 1. Cream should not be held at well-water temperature more than two days. Bitter flavors are often noticed in cream which is hung in the well or set in the spring for three or four days.
2. Set the starter with a small amount of mother starter at 70 degrees F. rather than a large amount at 55 degrees. (One quart of starterline to 100 pounds of pasteurized skim-milk is sufficient.)
3. Milk clean cows in clean stables by clean hands.

IX. WEEDY AND FOOD FLAVORS: Indicated by weedy and food smell.

Causes: 1. Cows feeding on weeds.
2. Feeding strong scented food just before or during milking.
3. Exposing milk in an atmosphere laden with objectionable food flavors.

Remedies: 1. By giving cows a plenty of good pasture feed they will not eat weeds enough to flavor the milk.
2. Do not feed silage, brewer's grain or slightly decayed feed shortly before or during milking.
3. Do not keep milk in the same room with feed of any kind.

X. UNCLEAN FLAVORS: Unclean smell or taste.

Causes: 1. Dirty cans and milk utensils.
2. Dirty water may cause an undesirable aroma, but nothing objectionable to the taste.

3. Impure air and dirty starter may give an undesirable taste, but nothing objectionable in aroma.
4. When the judges fail to find words to describe a flavor, this expression is used as a last resort. See description of unclean flavors in cheese.

BODY OR TEXTURE DEFECTS

I. WEAK BODY. Soft and weak when pressed with thumb or finger; sometimes coarse in appearance.

Causes:
1. Ripening, churning and working at too high temperatures.
2. Cream not cooled long enough before churning.
3. Too much moisture in butter.
4. Character of the butter-fat.

Remedies:
1. Ripen, churn and work the butter at as low a temperature as practicable.
2. Remember that with cream churned right after being cooled down from 60 degrees, the churning temperature may have to be lowered to 50 or below, while cream kept at 55 over night may be churned safely at 57 to 58.
3. By employing the ordinary methods of washing and working not over 16 per cent of moisture will be left in the butter.
4. Change the feed of the cows. This trouble is seldom found in the butter-fat from mixed herds.

II. GREASY BODY: No grain, dead in appearance.

Causes:
1. Over-churning of the butter.
2. Over-working.
3. Washing the butter granules in too warm wash water.
4. Churning and working at too high temperatures.

Remedies:
1. Stop churning when the granules are about the size of wheat kernels.
2. Work the butter no more than is necessary.
3. Never use wash water above the temperature of the buttermilk when drawn.
4. Churn at low temperatures so that the butter granules will not stick together while washing.

III. Body Showing Too Much Moisture:

Causes: 1. Stopping the churn when the granules are too fine.
2. Under-working the butter.

Remedies: 1. Churn granules to the size of wheat kernels.
2. Work but once and until smooth and waxy.

IV. Milky Brine:

Causes: 1. Churning at too high temperatures.
2. Over-churning.
3. Improper washing.

Remedies: 1. Churn at lower temperatures so that the granules will not stick together.
2. Churn until the granules are about the size of wheat kernels.
3. Fill the churn with wash water to about the same height in the churn as the cream occupied when the churning started.

V. Color: Mottled appearance.

Causes: 1. Uneven distribution of the salt.
2. Using too cool or too warm wash water.
3. Not enough moisture in butter when worked.
4. Churning too warm.

Remedies: 1. Distribute and work the salt evenly.
2. Have the wash water about the same temperature as that of the buttermilk when drawn.
3. Leave enough moisture in the butter so that the salt will readily dissolve while working.
4. Churn the cream at a temperature low enough to prevent the granules from sticking together and allow the buttermilk to be washed out, then salt is quickly and more easily distributed and dissolved. Streaked butter is simply a mild case of mottles.

VI. Color Specks: Tiny color specks which appear throughout the butter.

Causes: 1. Using a poor grade of color.
2. Allowing the color to become too old.
3. Keeping the color at too high a temperature.

Remedies: 1. Buy only the best grade of color.
2. Buy in small quantities.
3. Never keep the color near a radiator or boiler.

VII. Salting Defects. Indicated by taste.

Causes: 1. Too coarse, gritty.
2. Unevenly distributed.
3. Too low or too high.

Remedies: 1. Leave enough moisture on the granular butter and work sufficiently to dissolve the salt.
2. Distribute evenly and revolve the churn a few times before setting rollers in motion.
3. Too little salt often fails to bring out the best flavor. Too much salt leaves a coarseness of taste that covers up the fine, creamy flavor so much desired in butter.

VIII. Package Defects:

Causes. 1. Bad appearing, dilapidated package.
2. Badly trimmed and dirty on top or sides.
3. Butter not packed solid.

Remedies: 1. The package and covers must look neat and clean and not be too old.
2. Cut top of butter with a string or wire and wipe the dust out of the cover before placing it on the tub.
3. Pack small amounts of butter in the tub at a time and use the packer after each addition. Strip the tub from the butter occasionally and note the appearance of the butter surface.

TESTING BUTTER FOR FAT (Ross)

A sample of butter about twice as large as a hen's egg should be made up, parts being taken from different places in the package or the churn. This insures a representative sample. The sample should be placed in a lightning-top sample jar or in a glass-stoppered jar; a quart fruit-jar will be found useful for this purpose. The butter should then be heated, with constant stirring, until it has the consistency of thick cream. The pur-

pose of heating and mixing is to distribute the moisture evenly throughout the sample. If the butter is melted too far, it will have to be cooled before being weighed out for the test. The sample must be kept constantly stirred while cooling in order to keep the moisture evenly distributed; if this stirring is not done, the moisture will tend to collect in the center and an accurate test cannot be made. Three or four grams of the prepared sample is weighed out into a cream bottle; if more than this quantity is used, the fat column will be so large that it cannot be read in the bottle. The sample is then made up to approximately 18 grams by adding water. The purpose of adding water is the same as in testing cream: it retards the action of the acid. About 12 c.c. of acid is then added; this quantity is sufficient because the solids not fat in butter are present in comparatively small proportions. The tests should be made in duplicate. From this point the test is conducted in the same manner as is the test for fat in cream (see p. 119). The fat column should be kept at the proper temperature, and glymol should be used in reading the completed test.

BUTTER-MOISTURE TESTS

A number of methods have been devised for testing the percentage moisture in butter which give satisfactory results in commercial work. The following is representative.

Cornell butter-moisture test (Ross)

When butter is heated, a covering of casein will collect over he surface of the sample. When the sample becomes quite hot, his covering is of snow-white color. After heating the sample or a time, the foam begins to subside and loses its snow-white olor, changing to a dirty brown. By comparison with the hemical method, it was found that when the foam had lost its

snow-white color the sample had given up all of its moisture. The appearance of the dirty-brown color was a sure indication that all of the moisture had passed off, and if the sample was not removed from the flame at this point, some of the butter would volatilize.

When butter is heated in a direct flame, it is difficult to drive off all of the moisture and yet not volatilize some of the fat. In order to obviate this serious difficulty, a thin sheet of asbestos was placed between the flame and the container of the sample. The device worked admirably. A heat high enough to drive off all of the moisture is obtained, but the flame is so tempered

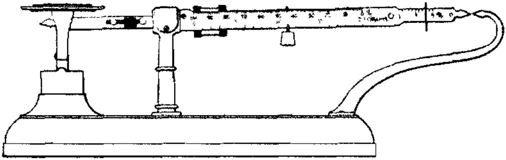


FIG. 51. — Cornell butter-moisture scale by which the percentage of moisture can be read direct.

by the sheet of asbestos that the sample of butter will not char unless left on the sheet of asbestos an unnecessary length of time. The asbestos sheet is often employed in culinary work for the same purpose as in this test.

The apparatus used in the Cornell moisture test is an alcohol lamp, stand, asbestos sheet, hot pan lifter, aluminum cup for holding the sample, and a special moisture scale. The scale is specially adapted for moisture work, but may be used as a cream scale in operating the Babcock test (see Fig. 51).

The scale has a tare weight for balancing the cup and a large and small weight for weighing the sample and obtaining the percentage of moisture. The beam has two rows of figures

which give readings with the larger weight. The lower row gives readings in grams and the upper row in percentages. The smaller weight gives readings in grams when the weight is moved from 1 forward. Each notch represents .02 gram, the total value of the small scale being .2 gram. When the small weight is moved from 0 backward, each notch represents a loss of .1 per cent of moisture when 20.2 grams of butter are used. The small weight is intended to be used only in moisture work. In using the scale for Babcock work, the small weight is not used but is left at rest on the figure 1. Then when the scales are balanced, the small weight is negligible. Care must be taken not to let any draft of air, as from an open window, strike the scales when in use, as they are so sensitive that a very slight current of air would throw them out of balance. The scales will give readings in percentages only when 20.2 grams of butter have been weighed or, in other words, when the large weight is on 20 (of the gram scale) and the small weight is on zero.

The cup used is of cast aluminum and is durable and perfectly smooth. The absence of creases or crevices allows it to be cleaned and dried thoroughly.

Taking the sample.

It is necessary that a representative sample be taken for a moisture test. If the butter is sold in tubs, the sample should be taken from the tub with a butter trier, after the butter has been packed. It is best to take three drawings — one from near the edge, one from the middle, and one halfway between the edge and the middle. Some butter-makers test the butter as soon as it is worked. This is a mistake, since considerable moisture is lost in the process of printing and packing.

Preparing the sample for testing.

This is one of the most important and difficult operations in he process of testing butter for moisture. Water and fat do ot readily mix, and there is a constant tendency for the water

to ooze out of the butter. When the water separates from the butter, it is difficult to distribute it again evenly through the sample. After repeated trials of several months we found the following method of preparation to give the most uniform results:

Place the sample to be tested in a glass container which has a fairly wide mouth, so that the sample can be stirred. A quart fruit jar is useful for this purpose. Then hold the container in warm water until the butter begins to melt. Remove the container from the warm bath and thoroughly mix the melted with the unmelted butter. In the laboratory a long-bladed cheese knife was found very useful for mixing the butter. A wooden stirrer should not be used, as it is likely to take up moisture from the sample. The process of melting the butter and mixing it with the unmelted butter is repeated until the sample contains no lumps and the entire mass is about the consistency of thick cream. The container is then transferred to cold water and the sample thoroughly mixed as the butter cools. There is a tendency for the fat around the outside of the container to harden rapidly and force the water toward the center of the jar. For this reason special care must be taken to keep the butter scraped off the sides of the container and thoroughly mixed with the softer butter in the center of the jar. When the sample is all of about the texture of ordinary butter, the mixing may be stopped. If the process has been properly done, the water will be evenly distributed throughout the sample and any desired amount of the latter may be removed for testing.

The above process is a modification of the one recommended by the Association of Official Agricultural Chemists. The Official method directs to shake the sample instead of stirring it when cooling. In our tests we have obtained better results by stirring. In melting the butter, do not use too hot water, as there is danger of driving off some of the moisture. The

jar containing the sample should be kept covered to prevent the evaporation of moisture.

Operation of the test.

A sample of butter is taken and prepared as previously described (see p. 276). After the cup is thoroughly cleaned and dried, it is placed on the scales and balanced by means of the tare weight on the round bar attached to the beam of the scales. The large weight should rest on the zero mark (of the gram scale) and the small weight on 1 while the cup is being balanced. The cup should not be balanced until it is about the same temperature as that of the room. After the cup is balanced, the larger weight is moved to the 20 mark (of the gram scale) and the small weight to the zero mark. Butter from the prepared sample is then added to the cup until the scales are *accurately* balanced. The alcohol lamp is then placed under the iron stand and the asbestos sheet placed on the stand. The lamp is lighted and the cup placed on the asbestos sheet. It is well to light the lamp at least two or three minutes before placing the cup on the asbestos, in order to heat the asbestos and save time. The heat of the flame may be increased or diminished by raising or lowering the wick. The cup should always be handled with the hot pan lifter, as by so doing it will be kept clean and errors in weight due to dirt on the cup will be avoided.

While the sample is heating it should be shaken from time to time, as this breaks up the blanket of casein on the surface and hastens the escape of moisture. As soon as the casein has lost its snow-white color, the cup should be removed from the flame. When the moisture has all been driven from the sample, a slightly pungent odor may be noticed. This may also be used as a guide to tell when the sample has been heated enough. The foam begins to subside at this point. Often one or two small pieces of casein are slow to give up their moisture. This s indicated by the snow-white color of the pieces. Evaporation

can be hastened by shaking the sample with a rotary motion and thoroughly mixing these pieces with the hot liquid. If this is not done, one might have to heat the sample so long that some of the fat, which had already given up its moisture, would volatilize.

After all the moisture is driven off, the sample is allowed to cool to room temperature. While cooling, the cup should be covered with something (a sheet of paper will do) to prevent the sample taking up moisture from the atmosphere. After cooling, the cup is placed on the scales. The sample is lighter than before heating, because it has lost its moisture. The bar of the scales will therefore remain down. The weights are then reversed until the scales just balance.

Each notch that the larger weight is reversed has a value of 1 per cent (reading on the upper scale), and each notch that the smaller weight is reversed has a value of .1 per cent. If, for example, after heating, the scales just balance when the larger weight rests on 15 (upper scale) and the smaller weight rests on .2, it would mean that the sample contained 15.2 per cent moisture.

It may be thought by those using the Cornell test for the first time that the use of the asbestos sheet is unnecessary. It is true that any one who is very familiar with moisture work may heat butter in a direct flame and get fairly accurate results. But the heat of the flame is so intense and butter volatilizes so easily that the use of the asbestos sheet is always advisable.

TEST FOR SALT IN BUTTER (Troy)

Apparatus.

One 10 c.c. burette graduated to tenths of a c.c.

Babcock milk pipette.

One white cup.

One pint bottle marked to show the line at the upper surface of the liquid when the bottle contains 300 c.c.

Reagents.

Standard tenth normal silver nitrate solution. (Dissolve 17.5 grams of so-called chemically pure silver nitrate in water and make the volume up to 1000 c.c.)

Ten per cent solution of potassium chromate for indicator.

Making the test.

Soften by warming to a pasty condition three or four ounces of the butter in a fruit jar or wide-necked bottle. Mix thoroughly with a table knife or strip of wood in order to evenly distribute the moisture. Weigh into a dish ten grams of the mixed butter. Wash it with hot water into the pint bottle. (If a moisture test was made on ten grams of the butter, the substance remaining in the cup may be used for the salt test.) Add enough hot water to bring the surface of the water up to the 300 c.c. mark on the bottle. The melted fat should be above the 300 c.c. mark. Place the stopper in the bottle and shake it vigorously for about half a minute. Let the bottle rest for about five minutes, then draw a Babcock milk pipette (17.6 c.c.) of the watery portion and place it in a white cup. Add three or four drops of the potassium chromate solution, stir, and run in the standard silver nitrate solution from the burette, with constant stirring until the color of the substance in the cup changes to a permanent brownish red. Read on the burette scale the amount of standard silver nitrate solution used.

Each c.c. of standard silver nitrate solution used equals one per cent of salt in the butter.

WHEY BUTTER

In sections of the country in which large quantities of cheese re made, it is now customary to run the whey through a eparator, collecting the fat, which is then made into butter, for the making of cheese there is an appreciable amount of fat hich passes off in the whey. If this is removed by separation,

a good quality of butter can be made from it, and its sale adds materially to the returns received from the milk.

RENOVATED BUTTER

In sections in which large quantities of butter are made on the farms, much of it is of poor quality, and in such small quantities that it cannot be marketed to advantage. Butter of this sort is usually traded in at the local grocery store and finally finds its way to the renovating factories, where it is put through a special process of clarification, and re-working. The renovating process removes many of the bad flavors and results in a fairly uniform finished product, which is then put on the market as renovated or process butter. The manufacture of this butter is subject to supervision and inspection by the National Government. Process butter is defined by an Act of Congress, approved May 9, 1902, as follows:

"This grade or kind of butter may be made from one or more lots or parcels of butter which has been or have been 'subjected to any process by which it is melted, clarified, or refined and made to resemble genuine butter, always excepting "adulterated butter" as defined by this act.'

"The butter, to be subject to this definition, must have been melted — that is, so affected by heat as to become of sufficient fluidity to move in a continuous stream of even consistency from one vessel to another by pouring or pumping, because butter cannot be 'clarified or refined' unless it be melted to that degree.

"The butter must, besides melting, have been subjcted to some process by which it is 'clarified or refined.' Butter, or melted butter, may be clarified or refined by skimming, aërating, washing, and other processes, through the action of heat, cold, agitation or motion, or rest.

"Butter thus melted and clarified or refined becomes an oil or

fat almost free from taste and odor. To be again 'made to resemble genuine butter' it must have restored to it the butter characteristics or similitude of texture, granulation, and flavor. For this purpose the processed or renovated butter is usually mixed with milk or skim milk, or buttermilk, or cream, sweet or sour, and granulated by cooling. It may or may not have common salt or artificial coloring added. To 'resemble genuine butter' the article must have passed through these or other processes subsequent to melting, so that it looks, smells, and tastes like 'butter,' having a similar appearance, consistency, texture, and flavor."

The United States Department of Agriculture uses the form of report blank shown below in its official inspection of the manufacture of renovated butter:

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ANIMAL INDUSTRY

DAIRY DIVISION

Report of Renovated Butter Factory Inspection for Week Ending . . . , 191. . . .
Number of inspections made Monday, Tuesday, Wednesday, Thursday, Friday, Saturday.
Factory No. . . . District of. . . . .
Business name of establishment . . . .
Name of owner or company . . . .
Post-office address . . . .

SANITARY CONDITION

1. Are surroundings clean and in sanitary condition? . . . .
2. Is interior of factory, floors, drains, walls, partitions, stairs, etc., in sanitary condition? . . . .
3. Is ventilation good? . . . .
4. What is the general condition of all apparatus and utensils in regard to cleanliness? . . . .

MATERIALS USED

. Packing stock — Quality . . . . Grade . . . .
. Estimate what per cent, if any, is rancid, sour, cheesy, moldy, unclean, or otherwise objectionable . . . .
. . . .

7. Are the good and inferior grades of packing stock mixed or made up separately? . . . .
8. At what temperature is oil during blowing process? . . .
9. What disposition is made of the oil and grease collected from floors, drains, and catch basins? . . . .

10. Quality of milk used — whole, skimmed, pasteurized . . . . .
11. Quality of water for crystallizing tanks, etc. . . . .
    Source of supply . . .
12. Quality of air for blowing . . . .

FINISHED PRODUCT

13. Quality of finished product . . . . . .
14. How packed — tub, lb. , prints, lb. boxes, lb., , rolls, lb., . . .
15. Renovated butter condemned[1] lb. State for what reason . . .

16. Sample submitted for analysis was marked as follows . . .

Inspector.

METHOD OF WORKING SOME CREAMERY PROBLEMS (Guthrie)

Computing the percentage of fat in a vat of cream after starter is added.

If there is added to a vat of cream some skimmed-milk starter, the number of pounds of fat in the cream is not changed, but the percentage of fat is decreased. There is not enough fat in skimmed milk to be considered.

PROBLEM 1

A vat contained 300 lb. of 35 per cent cream. To this amount of cream was added 25 per cent of skimmed-milk starter. What percentage of fat was there in the mixture?

The 300 lb. of cream was increased by 25 per cent of its own weight.

$300 \times .25 = 75$, number of pounds of starter added

$300 + 75 = 375$, number of pounds of cream and starter

Another way to find the number of pounds of the mixture is to regard the weight of the cream as 100 per cent. Since 25 per cent was added the weight of the mixture was 125% of what it was before adding the starter. $300 \times 1.25 = 375$, number of pounds of cream and starter.

In the original amount of cream there was 105 pounds of fat ($300 \times .35 = 105$). There was the same number of pounds of fat after the

[1] Whenever renovated butter is condemned, notice should be sent immediately to the Chief of Bureau of Animal Industry.

starter was added. The number of pounds of the mixture and the number of pounds of fat in the mixture are given to find the percentage of fat. This is done by dividing the number of pounds of fat by the total weight of the mixture.

105 ÷ 375 = .28

.28 × 100 = 28%, fat in mixture. *Answer.*

Value of salted versus unsalted butter.

PROBLEM 2

A creamery that has been receiving 1000 lb. of fat daily has been making salted butter and getting an overrun of 18 per cent. It has an offer of an increase in price from 25 cents to 25½ cents for unsalted butter. Considering that the overrun would be 2½ per cent less for unsalted butter, which is the better proposition?

1000 × .18 = 180, number of pounds overrun for salted butter

1000 (lb. fat) + 180 (lb. overrun) = 1180, number of pounds butter

$.25 × 1180 = $295, value of salted butter

1000 × .155 = 155, number of pounds overrun for unsalted butter

1000 (lb. fat) + 155 (lb. overrun) = 1155, number of pounds butter

$.255 × 1155 = $294.52, value of unsalted butter

$295.00 − $294.52 = $.48, in favor of the salted butter. *Answer.*

PROBLEM 3

A creamery man separates 700 lb. of cream testing 41 per cent fat. Patron X brings 150 lb. of cream testing 30 per cent fat, and patron Y brings 100 lb. of cream testing 35 per cent fat. The creamery man dumps these two batches of cream into the ripening vat with the 700 lb., and then adds 200 lb. of whole-milk starter testing 3.4 per cent fat. Compute the fat test of the cream in the ripening vat.

700 × .41 = 287.00
150 × .30 = 45.00
100 × .35 = 35.00
200 × .034 = 6.80
1150 373.80

373.8 (total lb. fat) ÷ 1150 (total lb. in mixture) = .325

.325 × 100 = 32.5 per cent, fat test of cream. *Answer.*

Computing the amount of cream necessary to make a cream-gathering route profitable.

Very often when a cream route is newly started it will not pay for itself, but if it is handled properly it will become a paying route.

Therefore, in (*a*) the cost of manufacture is not considered; also it should be noted that the overrun is the only source of profit so long as the same price is paid for the raw product as is received for the finished one.

PROBLEM 4

(*a*) How many pounds of cream testing 35 per cent fat must a hauler gather per day to pay his daily wages of \$3, considering that the same price (25 cents) is paid for the fat that is received for the butter, that the overrun is 18 per cent, and not considering the cost of manufacture?

(*b*) How many pounds of cream testing 35 per cent fat must a hauler gather per day to pay his daily wages of \$3, considering that the same price (25 cents) is paid for the fat that is received for the butter, that the overrun is 18 per cent, and that the cost of manufacture is 3 cents per pound of butter?

(*a*) 1 lb. (of cream) × .35 = .35 lb., amount of fat
.35 × .18 (overrun) = .063, number of pounds overrun
\$.25 × .063 = \$.01575, value of overrun per pound of 35 per cent cream
\$3 (wages) ÷ \$.01575 = 190.47, number of pounds of cream necessary for the hauler to gather in order to pay expenses, as per (*a*). *Answer.*

PROOF

190.47 × .35 = 66.6645, number of pounds fat
66.6645 × .18 (overrun) = 11.9996, number of pounds overrun
\$.25 × 11.9996 = \$2.9999, wages per day

(*b*) 1 lb. (of cream) × .35 = .35 lb., amount of fat
.35 × .18 (overrun) = .063, number of pounds overrun
.35 + .063 = .413, number of pounds butter to 1 lb. cream
\$.25 × .35 = \$.0875, cost of 1 lb. cream
\$.03 × .413 = \$.01239, cost to manufacture butter from 1 lb. of cream
\$.0875 + \$.01239 = \$.09989, total cost of butter in 1 lb. of cream
\$.25 × .413 = \$.10325, receipts of butter from 1 lb. of cream
\$.10325 − \$.09989 = \$.00336, profit on 1 lb. cream
\$3 (wages) ÷ \$.00336 = 892.85, number of pounds of cream necessary for the hauler to gather in order to pay expenses, as per (*b*). *Answer.*

892.85 × .35 = 312.4975, number of pounds fat
312.4975 × .18 (overrun) = 56.2495, number of pounds overrun

312.4075 + 56.2495 = 368.747, number of pounds butter
\$.03 (cost of manufacture) × 368.747 = \$11.062
\$11.062 (cost of manufacture) + \$3.00 (wages) = \$14.062
\$.25 × 56.2495 (lb. overrun) = \$14.062

Creamery dividends.

PROBLEM 5

A creamery with a capital stock of \$6200 receives 184,475 pounds of fat and pays 30.22 cents a pound for it. The overrun of the butter made is 22.53 per cent, and the butter is sold for an average price of 31.26 cents per pound. The sum of \$334.50 is received for buttermilk. The operating expenses amount to \$13,793. It is to be considered that \$5200 of the \$6200 capital stock is for building, land, and equipment. With a depreciation in value of 15 per cent on the \$5200, what dividend could be declared?[1]

\$.3022 × 184,475 = \$55,748.34, amount paid for fat
\$55,748.34 + \$13,793.00 (expenses) = \$69,541.34, total expenditure
184,475 × .2253 (overrun) = 41,562.21, number of pounds overrun
184,475 + 41,562.21 = 226,037.21, number of pounds butter
\$.3126 × 226,037.21 = \$70,659.23, receipts for butter
\$70,659.23 + \$334.50 (receipts for buttermilk) = \$70,993.73
\$70,993.73 − \$69,541.34 = \$1452.39, net profit without depreciation
\$5200 (value of property) × .15 = \$780, depreciation
\$1452.39 − \$780.00 = \$672.39, net profit
\$672.39 ÷ \$6200 = .10845
.10845 × 100 = 10.845 per cent dividend, or 10.845 cents on a dollar. *Answer.*

Computing the rate in a coöperative creamery.

In a coöperative creamery the patrons are often paid a certain rate a pound for their fat. This rate is obtained by subtracting the total expenses from the gross receipts and dividing the remainder by the total number of pounds of fat delivered by the patrons. The quotient is the rate to be paid each patron a pound for his fat.

PROBLEM 6

The pounds of milk, the fat tests, and the pounds of fat delivered by ten creamery patrons are given in the following table. Find the rate and the amount of money due each patron.

[1] Usually the depreciation in average creamery property is about 15 per cent. This 15 per cent should be put in a sinking fund to be used in purchasing new apparatus.

Patron Number	Pounds of Milk	Test (Percentage)	Pounds of Fat
1	1,500	4.0	60.00
2	1,000	3.9	39.00
3	940	4.2	39.48
4	860	3.8	32.68
5	3,500	5.0	175.00
6	1,400	4.5	63.00
7	780	4.7	36.66
8	600	4.6	27.60
9	970	4.3	41.71
10	775	3.9	30.22
Total			545.35

This gives a total of 545.35 lb. of fat delivered. With an overrun of 20 per cent there would be obtained from the 545.35 lb. of fat, 654.42 lb. of butter (545.35 × 1.20 = 654.42), which at 32 cents per pound would equal $209.41 ($.32 × 654.42 = $209.41). Assume that the cost of making the butter was $10. Subtracting this from $209.41, there is left $199.41 to pay for the fat ($209.41 − $10.00 = $199.41). $199.41 ÷ 545.35 = .36565, rate to be paid per pound of fat. *Answer.*

Multiplying each patron's fat by this rate will give the money to be paid each one. The amounts are shown in the following table:

Patron Number	Pounds of Fat	Rate	Amount of Payment	
1	60.00	.36565	$21.94	Answer
2	39.00	.36565	14.26	Answer
3	39.48	.36565	14.44	Answer
4	32.68	.36565	11.95	Answer
5	175.00	.36565	63.99	Answer
6	63.00	.36565	23.04	Answer
7	36.66	.36565	13.40	Answer
8	27.60	.36565	10.09	Answer
9	41.71	.36565	15.25	Answer
10	30.22	.36565	11.05	Answer

The rate should always be carried to the fifth decimal place, and when the fifth decimal place is a zero the rate should be carried to six

decimal places. If the rate were not so carried out, there would be a considerable amount of money undivided.

Computing the average price of butter for one year.

PROBLEM 7

In a creamery where the amount of butter sold and the price received a month were as follows, what was the average price received a pound of butter for the year?

January, 5000 lb. at 30 cents per pound
February, 4900 lb. at 30.5 cents per pound
March, 5100 lb. at 31 cents per pound
April, 5500 lb. at 29 cents per pound
May, 9000 lb. at 25 cents per pound
June, 12,000 lb. at 23 cents per pound
July, 10,000 lb. at 24 cents per pound
August, 8000 lb. at 25 cents per pound
September, 7000 lb. at 26 cents per pound
October, 6000 lb. at 27 cents per pound
November, 5400 lb. at 27.5 cents per pound
December, 5100 lb. at 28 cents per pound

This problem is worked as follows:

January,	$.30	×	5,000	=	$1,500.00
February,	$.305	×	4,900	=	$1,494.50
March,	$.31	×	5,100	=	$1,581.00
April,	$.29	×	5,500	=	$1,595.00
May,	$.25	×	9,000	=	$2,250.00
June,	$.23	×	12,000	=	$2,760.00
July,	$.24	×	10,000	=	$2,400.00
August,	$.25	×	8,000	=	$2,000.00
September,	$.26	×	7,000	=	$1,820.00
October,	$.27	×	6,000	=	$1,620.00
November,	$.275	×	5,400	=	$1,485.00
December,	$.28	×	5,100	=	$1,428.00
			83,000		$21,933.50

$21,933.50 ÷ 83,000 = $.26426, average price per pound for the year. *Answer.*

CHAPTER IX

CHEDDAR CHEESE

CHEDDAR or American cheese is a product made from cow's milk by bringing the larger part of the milk solids together into a condensed form by the coagulation of the casein and the expulsion of a part of the water. The chief purpose of making cheese from milk is to preserve the nutrients in such form that they can be kept for a long time and can be shipped conveniently. With the exception of a portion of the albumin, fat, milk-sugar, and ash, the solids in the milk are preserved in the cheese. The one constituent of the milk which is intentionally eliminated is the water.

Van Slyke and Publow [1] give the following sizes and styles of American cheddar cheese as they are found on the market.

NAME	SHAPE	APPROXIMATE SIZE	APPROXIMATE WEIGHT
		In. diam.	*Pounds*
1. Cheddar or export	Cylindrical	14–15	60–70
2. Flats or twins	Cylindrical	14–15	30–35
3. Home-trade	Cylindrical	11–13	20–25
4. Daisies	Cylindrical	12–13	20
5. Young America	Cylindrical	7–8	8–12
6. Longhorn	Cylindrical	5	12
7. Picnic	Cylindrical	4–5	1–2
8. Square	Rectangular	Various sizes	(3–4 in. thick)
9. Print	Rectangular	10 × 10 × 2⅝	10 (marked in blocks or prints)

[1] *Science and Practice of Cheesemaking*, Orange Judd Co.

COMPOSITION OF CHEESE

The chemical composition of freshly made cheddar cheese as determined from a large number of samples is given by Van Slyke [1] in the following table:

	Lowest	Highest	Average
Water	32.69	43.89	36.84
Total solids	56.11	67.31	63.16
Fat	30.00	36.79	33.83
Proteins	20.80	26.11	23.72
Salts, etc. (represented in ash)	3.12	7.02	5.61
Percentage of solids in form of fat	50.39	56.83	53.56
Ratio of fat to proteins	1 : 0.79	1 : 0.63	1 : 0.70

The above table may be regarded as representing the normal chemical composition of freshly made cheese from milk of average composition. The chemical composition is influenced by a number of factors which will be discussed in detail later.

QUALITY OF MILK FOR CHEESE-MAKING

What has been said regarding the sanitary quality of milk for butter-making in Chapter VIII applies with even greater force in the case of milk which is to be used for the making of cheese. In the case of butter, by far the larger part of the milk-serum is removed in the skimmed milk and the buttermilk, thus tending to remove from the finished butter any undesirable flavors or odors which might be contained in the fresh milk. In cheese-making, however, there is little opportunity to get rid of abnormal taints, and the purity of the milk is, therefore, of even greater importance than in the case of butter-making. The success of the cheese-making process really begins with

[1] New York Exp. Sta. Bul. No. 308.

the drawing of the milk from the cow and the conditions under which it is drawn, and the care which it later receives will very largely determine the quality of the finished cheese. It is, therefore, evident that the milk should be drawn under as clean conditions as possible. Those factors influencing the cleanliness of milk as described in Chapter VI for the production of market milk should be observed in producing milk for a cheese factory. Freedom from dirt and bacteria are of prime importance. As in the case of market milk, milk that is to be used for cheese-making should be cooled as promptly as possible in a manner which will reduce the temperature without subjecting the milk to additional contamination. This can be done by placing the cans in cold running water or ice water or by passing the milk over some form of cooler (see Chapter V). If a cooler is used, great care should be taken that the cooling process be done where the atmosphere is free from dust and odors, or the condition of the cooled milk may be worse than at the beginning. If the cans are set in cold water, they should be stirred frequently until the temperature has been reduced to approximately the desired point. The cheese-maker is primarily dependent on the quality of the milk which the patrons bring him for the quality of his finished product, and it should always be kept in mind that cleanliness and cooling are indispensible conditions in milk for cheese-making. It should also be remembered that strong feeds such as cabbage, rape, or onions should not be fed to cows which are producing milk for the cheese factory. The strong aroma from these feeds is almost sure to taint the milk and produce cheese of poor quality.

On its arrival at the factory, each can of milk should be carefully examined. If it shows any signs of souring or has a bad flavor or odor, it should not be accepted. With experience, the milk receiver can become very expert in judging the quality of milk by the senses of taste and smell. Under some

circumstances, it may be desirable to make additional tests of special lots of milk. One of the quick tests (see p. 301) for determining the percentage of acid may prove most useful in determining the quality of some milk. If there is suspicion of its containing microörganisms which will later cause gas or other undesirable fermentations, it may be necessary to make a curd test, which may be done as follows:

The Wisconsin curd test.

Pint glass jars, thoroughly cleaned and sterilized with live steam, are provided; they are plainly numbered or tagged, one jar being provided for each lot of milk to be tested. The jars are filled about two-thirds full with milk from the various sources; it is not necessary to take an exact quantity; they are then placed in a water tank, the water of which is heated until the milk in the jars has a temperature of 98° F. In transferring the thermometer used from one jar to another, special care must be taken to clean it each time in order to prevent contamination of pure lots of milk by impure ones.

When the milk has reached a temperature of 98°, add to each sample ten drops of rennet extract, and mix by giving the jar a rotary motion. The milk is thus curdled, and the curd allowed to stand for about twenty minutes until it is firm. It is then cut fine with a case knife, and stirred at intervals for one-half to three-quarters of an hour sufficiently to keep the curd from matting under the whey. When the cubes are quite firm, the whey is poured off and the curd left to mat at the bottom of the bottles if the old form of apparatus is used. The best tests are made when the separation of the whey is most complete. By allowing the samples to stand for a short time, more whey can be poured off, and the curd thereby rendered firmer. The water around the jars is kept at a temperature of 98°, the vat is covered, and the curds allowed to ferment in the sample jars for from six to twelve hours.

During this time the impurities in any particular sample

will cause gases to be developed in the curds so that by examining these, by smelling of them and cutting them with a sharp knife, those having a bad flavor, or a spongy or in any way abnormal texture may be easily detected, and thus traced to the milk causing the trouble.

By proceeding in the way described with the milk from the different cows in a herd, the mixed milk of which produced abnormal curds, the source of contamination in the herd may be located. Very often the trouble will be found to come from the cows drinking foul, stagnant water or from fermenting matter in the stable. In the former case, the pond or marsh must be fenced off, or the cows kept away from it in other ways; in the latter, a thorough cleaning and disinfection of the premises are required. If the milk of a single cow is the source of contamination, it must be kept by itself until it is again normal; under such conditions the milk from the healthy cows may, of course, safely be sent to the factory.

If undesirable fermentations develop in the vat, it may be desirable to make a curd test of the milk of each patron to determine the source of the tainted milk. It should always be kept in mind that the quality of the finished product is dependent on the quality of the milk as it is received at the factory.

RELATION BETWEEN THE COMPOSITION OF MILK AND THE YIELD AND COMPOSITION OF CHEESE

While the importance of good clean milk cannot be overestimated, its chemical composition is also of great importance in relation to the yield and quality of the cheese. The amount of fresh cheese which can be made from a given quantity of milk will depend primarily on the percentage of solids in the milk, the percentage of milk solids lost in the whey, and the percentage of moisture which is retained in the curd.

All of the milk solids are of some importance in the manu-

facture of cheese, but those which are of greatest value are the milk-fat and casein. These two solids constitute over 90 per cent of the solids in the cheese. Small amounts of albumin, milk-sugar, and other solids are retained in the cheese, but these are so small that they do not appreciably affect the yield. It is evident from the above that the yield of cheese will be influenced primarily by the amount of fat and casein in the milk, other conditions being equal. In general, the percentage of casein in milk follows a quite definite relation to the percentage of fat. In other words, milk rich in fat is also rich in casein, while milk low in fat is also low in casein; but the ratio between these two constituents is not exactly constant. In the richer milks, while the percentage of casein is also increased, it does not increase in exactly the same degree as does the percentage of fat. This means that in rich milk the ratio of the casein to the fat is slightly lower than in milk lower in fat-content. This is shown by the following table by Van Slyke and Publow:[1]

Per Cent of Fat in Milk	Per Cent of Casein in Milk	Ratio of Fat : Casein
3.00	2.10	1 : 0.70
3.25	2.20	1 : 0.68
3.50	2.30	1 : 0.66
3.75	2.40	1 : 0.64
4.00	2.50	1 : 0.62
4.25	2.60	1 : 0.61
4.50	2.70	1 : 0.60
5.00	2.90	1 : 0.59

Since the percentage of fat is the most variable solid in milk, the yield of cheese should be in nearly direct ratio to the fat-content of the milk. The effect of fat on the yield of cheese is shown by Van Slyke[2] as follows:

[1] Science and Practice of Cheesemaking, p. 172, Orange Judd Co.
[2] New York Exp. Sta. Bul. 308.

"Taking milk as it averages, we find the following variation of relation between fat and cheese yield in normal milks containing different amounts of fat. The cheese yield is based on a uniform percentage of water in the cheese, 37 per cent.

RATIO OF FAT TO CHEESE YIELD IN NORMAL MILK

FAT IN MILK	CASEIN IN MILK	AMOUNT OF CHEESE MADE FROM 100 POUNDS OF MILK	AMOUNT OF CHEESE MADE FOR EACH POUND OF FAT IN MILK
per ct.	*per ct.*	*lb.*	*lb.*
3.00	2.10	8.30	2.77
3.25	2.20	8.88	2.73
3.50	2.30	9.45	2.70
3.75	2.40	10.03	2.67
4.00	2.50	10.60	2.65
4.25	2.60	11.17	2.63
4.50	2.70	11.74	2.61
4.75	2.80	12.31	2.59
5.00	2.90	12.90	2.58

"Casein, as we have shown, does not increase as rapidly as fat does in milk, and, therefore, milk richer in fat usually contains less casein in proportion to fat than does milk less rich in fat. In harmony with this condition and as a result of it, the amount of cheese made for a pound of milk-fat decreases as the percentage of fat in milk increases. This is clearly shown in the preceding table.

"An interesting fact shown in this table is that the rate of decrease of the ratio of fat to cheese yield is less rapid as the percentage of fat in milk increases. Thus, in the case of milks containing 3 and 3.25 per cent of fat, the decrease of cheese yield in relation to fat is from 2.77 to 2.73, a difference of 0.04 lb.; between 3.25 and 3.50, and also between 3.50 and 3.75, the decrease is 0.03; for each 0.25 per cent of increase of milk-fat;

from 3.75 to 4.75 per cent, the decrease in the ratio is only 0.02; and between 4.75 and 5.00 per cent, the decrease is only 0.01. This is explained by the well-known fact that, in the case of milk rich in fat, a smaller proportion of the fat is lost in cheese-making than in the case of milk poorer in fat."

The difference in value of milk with different percentages of fat for the purpose of cheese-making should be fully recognized both by the cheese-factory operator and by the milk producer, and the price paid for milk should be in proportion to its value for cheese-making.

In considering the influence of milk quality on its value for cheese-making, it should always be borne in mind that in addition to the greater yield from the milk rich in fat, there is also an increase in the market quality of the cheese. Other things being equal, cheese made from milk fairly rich in fat will be of higher flavor and finer texture and will bring a better price on the market.

In regard to the solids lost in the whey in the process of making cheese, Van Slyke[1] says:

"Fat is present in milk in the form of very minute globules. So small are these fat globules of milk that 5000 of them of average size, laid side by side, would reach only one inch. These are all scattered through the milk in enormous numbers. Now, when the rennet causes the casein throughout the whole mass of milk to solidify or coagulate, the fat globules are retained or imprisoned in the solidified mass just where they were at the instant that coagulation took place. When the curd-knife passes through the mass, immense numbers of the minute fat globules are exposed on every cut surface and numbers of these fall into the whey and are not retained in the cheese. The more finely we cut the curd and the more violently we handle the cut pieces of curd, the larger will be the number of fat globules that go into the whey.

[1] New York State Experiment Station, Bulletin No. 68.

"In regard to the loss of casein, the larger portion of loss appears to be in the form of fine particles of coagulated casein, which pass through the strainer, when the whey is drawn from the curd. These minute particles can readily be seen by letting *a pail of freshly-drawn whey stand until the casein settles,* and then pouring off the whey, when a noticeable quantity of finely-divided casein can be seen at the bottom of the pail. This passage of casein into the whey is not entirely avoidable, but is needlessly made greater by carelessness or violence in cutting the curd and in subsequent handling, by agitation while drawing off the whey, and by imperfect strainers. The amount of casein *that thus passes into the whey averages about 0.10 lb. for 100 lb. of milk.*"

The following table, compiled by Van Slyke from a large number of factories during an entire season, shows the amount of solids lost in the whey.

COMPOSITION OF CHEESE-FACTORY WHEY

MONTH	PER CENT OF WATER	PER CENT OF SOLIDS	PER CENT OF FAT	PER CENT OF PROTEINS (CHIEFLY ALBUMIN)	PER CENT OF SUGAR, SALTS, ETC.
April	93.17	6.83	0.40	0.73	5.70
May	92.98	7.02	0.38	0.81	5.83
June	92.99	7.01	0.31	0.88	5.82
July	93.05	6.95	0.35	0.83	5.77
August	93.08	6.92	0.38	0.80	5.74
September	93.18	6.82	0.41	0.85	5.56
October	93.04	6.96	0.38	0.98	5.60
Average	93.04	6.96	0.36	0.84	5.76

The percentage of moisture retained by the green curd is one of the most important factors in determining the yield of cheese. It also influences the character of the cheese and the

nature of the ripening processes. There is no relationship between the percentage of water in the milk and that in the fresh cheese, but there are many factors in the process of making which influence the amount of moisture which the finished cheese will contain. Some of these conditions are not within the control of the cheese-maker, while others are within his control and can be modified at will. It is possible for the experienced cheese-maker to vary the percentage of moisture in the cheese between rather wide limits and to make a product which will test within 3 or 4 per cent of any desired moisture-content. The conditions which affect the percentage of moisture and the yield of cheese are summarized by Fisk [1] as follows:

"1. Setting the milk at a high temperature reduces the loss of fat in the whey more than setting the milk at a low temperature. Setting at a high temperature increases the yield of the green and the cured cheese. This increase is probably due to the increased moisture-content of the cheese.

"2. An increase of rennet to a certain point increases the moisture-content of cheese. This is due to greater coagulation, and has the same effect as setting at a high temperature or cutting the curd hard.

"3. Cutting the curd fine causes a larger loss of fat in the whey than cutting the curd coarse. Coarse-cut curd increases the yield of green and of cured cheese and increases the moisture-content of the cheese. If great care is not taken and the pieces of curd are broken, the result will be the same as a fine cut.

"4. Cutting the curd soft reduces the percentage of moisture and the yield of the green cheese, and also increases the loss of fat in the whey. Cutting soft has the same effect as setting at a low temperature or as a small amount of rennet.

"5. A low acid at the time of removing the whey increases the yield of the green and the cured cheese. The low acid also increases the percentage of moisture in the cheese. If a high

[1] Cornell Exp. Sta. Bul. 334.

acid is developed, it not only reduces the yield and the percentage of moisture in the cheese, but also injures the quality of the cheese.

"6. Stirring the curd with the hand as the last of the whey is removed reduces the percentage of moisture in the green and the cured cheese. Stirring reduces the yield and causes a larger loss of fat in the whey.

"7. Holding the curd at a low temperature after the whey is removed increases the percentage of moisture in the green and the cured cheese and increases the yield.

"8. If the curds are piled deep, more moisture is retained in the green and the cured cheese. Piling the curds deep increases the yield of cheese.

"9. An increase of salt in the curd results in the reduction of moisture in the cheese.

"10. Pressing the curd fast reduces the yield because more fat is squeezed out of the curd. This loss of fat makes the cheese pressed fast appear to contain more moisture."

The percentage of moisture in the cheese is an important factor in controlling the development of the microörganisms which are largely responsible for the quality of the cured cheese. If the moisture is abnormally low, it may interfere with the development of those organisms which change the insoluble protein into soluble forms.

The texture of the cheese also is improved by the incorporation of a certain amount of moisture which increases its smoothness in the same way as does the milk-fat. Cheese low in fat should, therefore, contain a higher percentage of moisture than cheese rich in fat.

On the other hand, if the cheese contains too high a percentage of moisture, as may be the case in washed curd cheese, the development of undesirable bacteria may be favored at the expense of the lactic acid forms, resulting in the development of bad flavors and breaking down too rapidly.

METHOD OF MAKING CHEDDAR CHEESE

As soon as the milk is in the vat it should be stirred thoroughly to give it a uniform composition and acidity, as the amount and development of acid in the milk is one of the most important factors in the making of this type of cheese. It is important, therefore, that the cheese-maker determine *immediately the degree of acidity in the milk. Experienced cheese*-makers can judge with some degree of accuracy the amount of acid present by the sense of smell and taste, but this test is not sufficiently accurate to give satisfactory results in most cases. For the best results, the milk should be tested either by one of the common acid tests or rennet tests. If the acid test is used, it is desirable to have an apparatus which can be used quickly and easily. The use of Farrington's alkaline tablets [1] or a standard alkaline solution will serve this purpose. The following method recommended by Publow has proved satisfactory.

Publow acid test (see Fig. 52)

The apparatus consists of

1. A plain 5-pint bottle with an opening in the bottom, through which a brass pipe is connected in such a manner as to prevent leakage.
2. A small 2-oz. wash-bottle, fastened to the neck of the large bottle by a copper-band, and connected with rubber-corks and glass-tubing.
3. A plain 10 c.c. burette graduated in tenths, and a simple wire burette-holder.
4. A straight, non-bulbous, 9-gram pipette, which is easily cleaned.
5. A simple rubber-stoppered dropper-bottle.
6. A plain white cup and a stirring-rod.

[1] See page 134.

7. A small bottle containing 50 c.c. of a solution of caustic soda, which, when added to 2250 c.c. of water, makes 2300 c.c. of a $\frac{1}{10}$ normal alkaline solution. The large bottle is marked to show the level of 2300 c.c. in order to save measuring with a graduate each time.
8. A small bottle of phenolphthalein, to be used as an indicator.

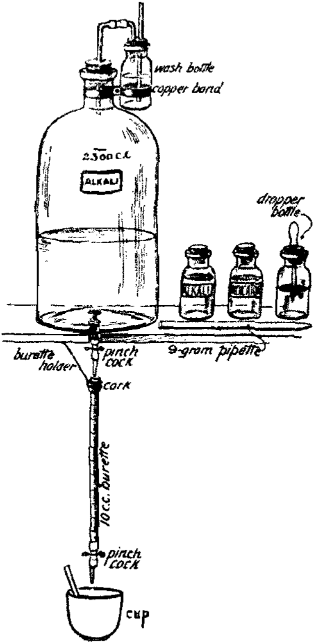


FIG. 52. — Publow acid test.

Very few of the cheese-makers and butter-makers are able to make and standardize their own solutions to be used in such tests. For this reason a concentrated solution is advised,

50 c.c. of which is sufficient to make 2300 c.c. of a $\frac{1}{10}$ normal alkaline solution. This small amount is not costly and can be sent through the mails for a few cents. When tightly corked, this solution will retain its strength indefinitely, so that it can be kept in stock in almost any place.

The indicator is made by dissolving 5 grams of dry phenolphthalein in 100 c.c. of 50 per cent alcohol. The commercial alcohol, which is about 95 per cent pure, can be used by diluting 50 c.c. of it with 50 c.c. of water. It can be purchased ready for use from dairy supply houses.

The preparation and successful handling of a good commercial starter for use in cheese-making or butter-making depends very largely on the amount of acid allowed to develop in the starter from day to day. Uniformity is one of the great factors of success in dairy work, especially in the manufacturing department, and one need only know this to appreciate the value of any simple test that will enable him to measure the acid in his product as closely as $\frac{1}{100}$ of one per cent.

By the use of such a test one is guided in controlling temperature and bacterial life associated with the manufacturing process, so that if the raw material reaches the cheese-maker or butter-maker in good condition there is no reason why he should not be able to turn out butter or cheese of uniform quality each day.

Directions for using the acidimeter.

In a convenient place erect a small shelf to support the large bottle. Cut a notch in the front or back of the shelf to allow the brass pipe to pass through.

Then add the contents of the small bottle of alkali to the large bottle, rinsing the small bottle several times, and each time pouring the rinsings into the large bottle. Then add soft water to the large bottle until the level reaches the mark filed on the bottle. You will then have 2300 c.c. of a $\frac{1}{10}$ normal alkaline solution.

The small wash-bottle attached to the neck of the larger one should be half filled with this solution. Then the rubber and glass connections are made between the two bottles.

The burette-holder is fastened underneath the shelf so that the alkali from the large bottle can enter it. The dropper bottle is then filled with indicator.

Measure with a pipette 9 grams of the substance (milk, whey, cream, or starter) which you wish to test, and place it in the white cup Add two drops of the phenolphthalein indicator. Then allow the alkaline solution to run into the cup from the burette, one drop at a time, until the fluid in the cup, which is being constantly stirred, shows a very faint pink color. By reading the graduations on the burette we can ascertain the amount of acid in the substance tested. Each $\frac{1}{10}$ c.c. of alkali represents $\frac{1}{100}$ per cent of acid in the fluid.

Amount of acid to be developed at each stage.

The amount of lactic acid developed depends largely on the condition of the curd, and no fixed amount can be accepted as a set rule. Other conditions equal, the acidity should be uniform from day to day.

The proper firming of the curd in the whey before too much acid has been formed is the secret of cheddar cheese-making, and with this fact in mind, the following directions should give accurate results:

EXPORT CHEESE		HOME-TRADE CHEESE
.20 to .21%	before adding rennet	.18 to .20%
.14 to .145%	before heating curd	.13 to .14%
.16 to .18%	before removing whey	.15 to .17%
.24 to .30%	when all whey is removed and curd is packed	.23 to .26%
.65 to .75%	before milling	.60 to .65%
.90 to .110%	before salting	.65 to .90%
.70 to .80%	in starter	.70 to .80%

Rennet tests

Many cheese-makers prefer some form of rennet test such as Monrad's or Marschall's to the alkaline solution acid test. The development of acidity in milk is due to the formation of lactic acid by the bacteria, and as the acidity increases, the number of bacteria increases also with great rapidity; in fact, the number of bacteria becomes quite large before the acidity increases enough to be measured by the alkaline tests. Hastings and Evans have found that the "rennet test is a much more delicate index of the bacteriological condition of the milk during the early phases of the acid fermentation than is the titration method. In other words, the curdling time by rennet under otherwise constant conditions is profoundly influenced by the most minute quantities of acid." Their conclusion is that since the rennet test is a much more sensitive measure of the bacteria and development of acid in the milk, it is the better test for the cheese-maker.

The Monrad rennet test is used by cheese-makers for determining the ripeness of milk. Five c.c. of rennet extract is measured into a 50 c.c. flask by means of a pipette; the pipette is rinsed with water, and the flask filled to the mark with water; 160 c.c. of milk is now measured into the tin basin from the cylinder and slowly heated to exactly 86° F.; 5 c.c. of the dilute rennet solution is then quickly added to the warm milk and the time required for coagulation noted.[1] Milk sufficiently ripe for cheddar cheese-making will coagulate in 30 to 60 seconds, according to the strength of the rennet extract used.

The Marschall rennet test is used for the same purpose as the Monrad test. The directions for this test are as follows: Fill the small glass with pure water to the mark, pour into it 1 c.c. of rennet extract and rinse the pipette in the same water.

[1] Decker, Cheese Making, Revised ed., 1909, p. 39.

Fill the cup with milk to the zero mark, add the rennet, mix thoroughly and allow it to stand. The sweeter the milk is, the longer it will take to coagulate, and the more milk will run out of the cup before the point of coagulation is reached, when the flow of milk will cease. The time required for coagulating the milk is shown directly by a scale on the inside wall of the cup (see Fig. 53).

It is important that the proper degree of acidity should be developed in the milk, and this may be done by allowing it to stand at a temperature favorable for the development of the acid-producing bacteria, which are already in the milk; or the ripening process may be hastened by the addition of starter. If starter is to be used, it should be prepared and handled in the same manner as described for use in butter-making (see p. 238). Special care should be taken that the starter is of good quality, and contains no organisms which will later develop undesirable conditions in the curd. If properly used, starters may be of much value in controlling undesirable fermentations and in hastening the ripening of sweet milk. The amount of starter which can be used will depend on the acidity of the fresh milk. Ordinarily from $2\frac{1}{2}$ to 5 per cent will be sufficient to give the desired results. Under certain conditions, a higher percentage may be desirable.

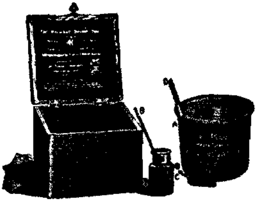


FIG. 53. — The Marschall rennet test.

Proper degree of ripeness.

The main purpose in ripening the milk is to develop the degree of acidity so that the curd will not remain in the whey more than two and three-quarters to three hours. The correct

degree of acidity will usually be shown by an acid test of 0.19 to 0.21 per cent, or when the milk coagulates at two and one-half spaces with the Marschall test or in forty-five to sixty seconds with the Monrad test. If the milk is ripened more than this, it is liable to cause trouble in the process of making and the later ripening of the cheese.

Coloring the milk.

Whether or not color should be added will depend on the requirements of the market, the quality of the milk, and the season of the year. Some markets require a cheese of light color, while others desire a highly colored cheese. If it is desirable to increase the natural color of the milk, it may be done by the use of anato or butter color, using from $\frac{1}{2}$ to 3 oz. to 1000 lb. of milk. Before adding the color to the vat, it should be diluted and then thoroughly mixed through the entire mass of milk.

Adding the rennet.

As soon as the proper degree of acidity has been reached, the rennet extract should be added. This step in the process is usually known as "setting" the milk. Rennet is a substance obtained from the stomach of a calf which is living on milk. The active principle is extracted from the tissue of the stomach and placed on the market in liquid form. The use of rennet in cheese-making is for the purpose of coagulating the casein.

Pepsin.

Commercial pepsin may be used in the place of rennet. This is a preparation made from the stomachs of sheep or hogs, and is usually placed on the market in the form of dry scale-pepsin. This pepsin is used by making a water solution which is then added to the milk in the same manner as rennet. Pepsin does not seem to work in very sweet milk as well as does rennet, but for milk which is fairly ripe, its action seems to be entirely satisfactory and produces a cheese equal in quality to that made with rennet extract.

The amount of rennet to be used will depend on

1. The acidity of the milk.
2. The strength of the rennet.
3. The temperature of the milk at setting.
4. The composition of the milk.

A sufficient amount should be used to coagulate the milk ready for cutting in twenty-five to thirty-five minutes. Under normal conditions from 2½ to 4 oz. a 1000 lb. of milk will be sufficient. Before the rennet is added to the milk, it should be diluted with pure cold water at approximately *one part of* rennet to forty parts of water. This is to make possible the more thorough distribution of the rennet through the entire mass of milk, and prevent its acting on the portions of the milk with which it comes into contact before it can be thoroughly distributed through the entire mass. The milk should be stirred for several minutes thoroughly to distribute the rennet. It should then be allowed to stand without disturbance, except that the surface should be stirred to prevent the rising of the cream until just before the milk begins to coagulate. As soon as coagulation begins, it should stand undisturbed until the process is completed.

Manipulating the curd

As soon as the curd is sufficiently firm, it should be cut into small pieces in order to allow the whey to escape. The proper stage for cutting may be determined in one of several ways. One of the most common methods is by inserting the forefinger obliquely into the curd and then slowly lifting it to the surface. If the curd breaks with a clean surface and the whey is clear and without milkiness, it is ready to cut. Another common method is to place the hand on the surface of the curd near the edge of the vat, gently pressing the curd away from the side. If it separates from the side of the vat without leaving any

particles of curd, it is ready for cutting. Publow gives the following rule as perhaps the most accurate one for determining when the curd is ready to cut:

"Two and one half times the period from adding rennet till the first thickening appears gives the time for cutting."

Method of cutting the curd.

It is important that the curd be cut into pieces of uniform size in order to insure their even contraction and expulsion of whey. This process is accomplished by the use of gang knives made either of steel or fine wire (see Fig. 54).

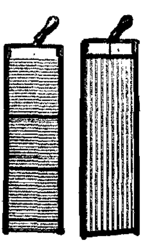


FIG. 54. — Wire knives for cutting the curd.

First the curd should be cut lengthwise of the vat by the use of the horizontal knife. This cuts it into slices or layers one-half inch thick. Next it should be cut crosswise of the vat with a perpendicular wire knife and, finally, cut lengthwise, using the same perpendicular knife. This combined cutting leaves the curd in small cubes with straight sides. In using the knives, great care should be taken not to break the curd, since this will permit the escape of the fat globules, and a larger percentage of fat will be lost in the whey. The more carefully the cutting is done, the smaller will be the loss of fat. In using the knives, they should be moved slowly and, in passing them through the vat, care should be taken to follow accurately the line of the last cutting, carelessness in cutting being sure to result in increased losses in fat and yield. Sometimes the cheese-maker may wish to vary the size of the cubes of curd in order to influence the expulsion of the whey and the control of the moisture. As soon as the curd has been cut, the whey begins to escape, the little cubes contract in size, and a thin film forms on the face of the cubes. After the curd has been

cut, it is important that the little cubes do not stick together again, since this would prevent the escape of the whey. In order to keep them separate, the curd should be stirred gently as soon as the surface film has become strong enough to prevent their being broken. At first, this stirring must be very gentle, but can become more vigorous as the cubes contract and become firmer. Breaking the cubes will result in an increased loss of fat and casein in the whey.

Heating the curd.

The chief purpose of the cheese-maker at this stage is to extract the whey from the little cubes of curd. This process can be hastened by heating or "cooking" the curd, a term which is somewhat misleading since the temperature applied is never sufficient to in any sense cook the curd, the purpose being simply to assist in the contraction of the cubes and the expulsion of the whey. The escape of the whey is probably due to the combined action of the rennet, the lactic acid, and the heat. The amount of heat to be applied, therefore, will be dependent on the first two factors, and it should be applied very gradually in order that it may penetrate the curd and avoid uneven heating. Ordinarily, the temperature should not be raised more than 2° F. in five minutes, and under some conditions it should be even slower than that. If heated too rapidly, the surface film of the cubes becomes too thick and prevents the escape of whey. Usually, the temperature should be raised to 96–100° F., but, under certain circumstances, a somewhat higher temperature may be required. The amount of fat in the milk will affect somewhat the degree of heat to be applied; other things being equal, milk rich in fat will require a higher temperature to accomplish a given result. At the close of the cooking process, the cubes of curd should be shrunken to less than one-half their original size and should be firm and rubber-like in texture. At this point, if a mass of curd is pressed firmly in the hand and then suddenly released, the cubes should fall

apart without any tendency to adhere to each other. Another method for determining the proper amount of cooking is by the "hot iron" test. On removal from the hot iron if fine silky threads about one-eighth of an inch in length are formed, the cooking process has reached the proper stage. At this point, the whey should have an acidity of .16 to .18 of 1 per cent, as shown by the acid test.

The cubes of curd will now settle to the bottom of the vat and the whey should be removed to the level of the curd.

Cheddaring the curd.

As soon as the proper degree of acidity has developed in the whey and the cubes of curd have reached the desired firmness, the remainder of the whey should be drawn off and the curd gathered in a shallow layer on either side of the vat, leaving an open channel in the center through which the whey can run off. Up to this point, the particles of curd should be kept separate and distinct, but they should now be permitted to mat together, forming a solid mass. When the curd has become sufficiently firm, it should be cut into blocks or strips six to eight inches wide. The blocks should now be turned over in order to prevent one surface from becoming cooler than the other, and also to hasten the escape of whey. After the curd has drained in this position for a few minutes, the pieces should be piled two deep, care being taken to see that the surfaces which were exposed to the atmosphere are now turned in. It is important that the temperature of the curd be kept uniform and the pieces should be turned frequently, each time turning the outer surfaces in, in order to prevent uneven cooling.

In the place of this matting process, some cheese-makers prefer to place the curd on draining racks where the whey is allowed to drain off through cheesecloth and the curd to mat down.

Milling the curd.

As soon as the curd has become sufficiently dry, and has developed the proper texture, it should be cut into small pieces

for the purpose of allowing any excess whey to escape and of putting the curd in such form that the salt can be evenly and thoroughly incorporated. This is accomplished by passing the cubes of curd through the curd mill, which cuts it into pieces of uniform size (see Fig. 55). This mill should be fitted

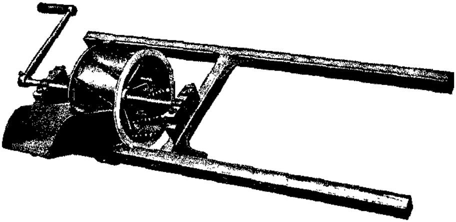


FIG. 55. — One type of curd mill.

with sharp knives which will cut the curd without crushing it, in order to avoid the escape of the fat globules from the curd. After it has been milled, it should be spread over the bottom of the vat, and if it contains gas or bad odors, thorough stirring and airing at this point will assist in their removal. The curd can be stirred most satisfactorily by means of a curd fork (see Fig. 56). It is important that the curd should be

FIG. 56. — Fork for stirring the curd.

kept warm during this process, and if the making process has been properly conducted, the curd should now contain no free whey which will escape by pressure from the hand. The matting and grinding process which have just been described con-

stitute the "cheddaring" of the curd, and it is from this process that this type of cheese derives its name.

Salting the curd.

Experience is required to determine the proper point at which the salt should be applied. The cheese-maker should take into account the percentage of acid in the whey, the length of strings by the hot iron test, and also the general condition of the curd. While the chief purpose of salting is to improve the flavor of the ripened cheese, it also assists in the removal of whey. The amount of salt to be added will vary with the requirements of the special market for which the cheese is intended, and also with the condition of the curd. If it shows signs of gas or is very soft, this condition may be improved by increasing the amount of salt, the moist curd requiring more salt since a greater portion of it will be lost in the whey during the pressing process. Under ordinary conditions, from 1½ to 2½ lb. of salt to each 1000 lb. of milk will be satisfactory. Before applying the salt, the curd should be spread evenly over the bottom of the vat and cooled to about 90° F. A good way to apply the salt is to sprinkle one-third of the amount to be used evenly over the curd by means of a fine sieve. The curd is then stirred with a curd fork, again spread out and another one-third of the salt applied in the same manner, this process being repeated until all of the salt has been applied. The salt should be free from lumps and of uniform size, that with fairly coarse grain being preferable to very fine, since it requires a longer time for it to dissolve and favors its absorption by the particles of curd before it has an opportunity to escape in the whey.

Pressing the curd.

As soon as the salt has been thoroughly incorporated, the temperature of the curd should be brought to about 80° F. It should now be placed in the cheese hoops and put in the press in order to bring the small pieces of cheese into close con-

tact into a form which will be convenient for handling. The pressing process also removes any free whey which may be left in the curd. If the temperature of the curd is correct and the pressing properly done, a cheese of close, even texture will result.

Before putting the curd in the hoops, they should be lined with specially prepared cheesecloth for the purpose of holding the finished cheese in shape and giving an even surface. A definite amount of curd should be weighed into the hoop in order

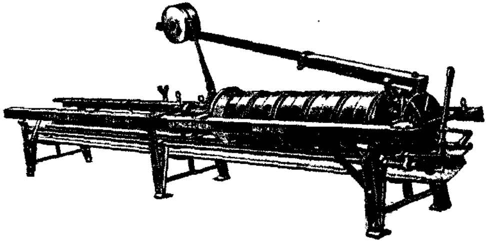


FIG. 57. — Sprague cheese press fitted with automatic pressure block.

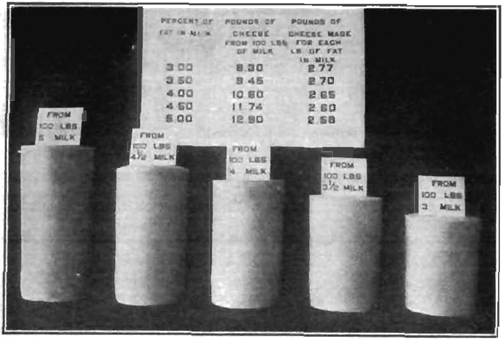
to insure the finished cheese being of uniform size, since cheese of uniform size sell better than those which are not. The cheese is now placed in the press and a moderate amount of pressure applied, the amount needed depending on the nature of the curd and the ease with which the pieces may be pressed and cemented together (see Fig. 57). After the cheese has been in the press for three-quarters to one hour, the pieces will be firmly cemented together, and it should then be removed from the hoop and dressed, which consists of removing all wrinkles from the cheesecloth bandage, trimming it so that it will extend about one inch over each end of the cheese and

placing the starched cap cloths over the ends. The cheese is then replaced in the hoop and held under constant pressure from 24 to 48 hours. This dressing is one of the important steps in the manufacture of cheddar cheese, as the better appearance will decidedly influence the price for which the product may be sold. At the close of the pressing period, the cheese are taken from the hoops and placed in the curing room.

Curing the cheese (see Plate XV)

When the finished cheese comes from the press, it is little more than green, sour milk curd, although certain ripening processes have already commenced, which must now be given an opportunity to ripen and develop the characteristics desirable in mature cheese. For this purpose, the cheese are placed in curing rooms where the temperature and humidity can be controlled. The more completely these factors are under control, the more certain will be the quality of the ripened cheese. The exact changes which take place in cheese during the ripening process are not fully understood, but in general the casein is acted upon by enzymes which change the insoluble compounds into soluble ones. At the same time the characteristic flavors develop in the cheese. The conditions of the curing room should be such as to prevent excessive evaporation from the cheese and also maintain a fairly constant temperature during the ripening period. It is generally agreed that low temperatures are better than high for the development of the best quality, both as to flavor and texture. The results of a large amount of work carried on by the New York Experiment Station are summarized as follows in bulletins 184 and 234.

"The loss of weight increased with increase of temperature, being on an average in 20 weeks 3.8 lb. to 100 lb. of cheese at 40° F., 4.8 lb. at 50° F., and 7.8 lb. at 60° F. The large-



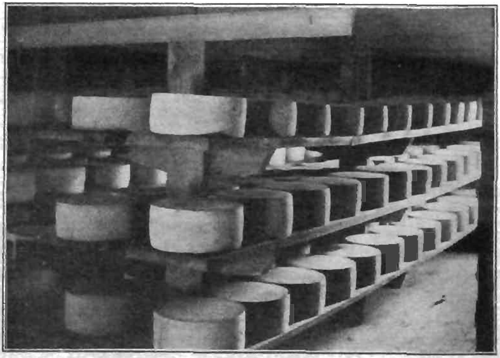


PLATE XV. — Yield of cheese from milk with different percentages of fat.
A cheese curing-room.

sized cheeses lost less weight to 100 lb. than the smaller-sized ones.

"Cheese cured at 40° F. was superior in quality to the same kind cured at higher temperatures. That cured at 50° F. was superior in quality to that cured at 60° F. The general averages of the scores at the end of 20 weeks were as follows: 95.7 at 40° F., 94.2 at 50° F., and 91.7 at 60° F. The difference in quality was confined in most cases to flavor and texture, the color and finish being little or not at all affected in cheese that was in good condition at the beginning.

"Of the cheeses made in 1899 those cured at 60° F. and below scored, on the average, almost 5 points higher on flavor, and 2.5 points higher on texture, than those cured at 65° F. and above. In 1900, the average difference in flavor of the lower temperatures was 5.1 points on flavor and 2.7 points on texture.

"The commercial qualities of the cheese were favorably influenced after six months in the case of those covered with paraffin, especially flavor. The loss of moisture was greatly lessened, amounting only to a fraction of a pound for 100 lb. of cheese at 40° F. and 50° F., and being only about one-fifth the average loss found at 60° F. with cheese not so treated. The cheeses were also perfectly clean and free from mold, while all the cheeses not treated with paraffin were covered with mold.

"Curing cheese at low temperatures increases the amount of cheese to sell, by preventing loss of moisture, and covering cheese with paraffin increases still more the yield of marketable cheese. This saving amounts to several dollars a ton. Also, the improved quality of cheese cured at low temperatures enables such cheese to bring a higher market price."

The rapidity of ripening is influenced by the temperature of the curing rooms. At temperatures between 60 and 70 degrees the casein breaks down rapidly and the cheese may be

ready for consumption at the end of two to three months. It is better, however, to hold the cheese at lower temperatures and allow four to six months for the ripening period. Many persons prefer a highly flavored mellow cheese which is secured by allowing a longer period for the ripening process, in some instances as long as one to two years.

TESTING CHEESE FOR FAT (Ross)

Samples of cheese for testing may be obtained in one of two ways: one plug may be taken near the rind of the cheese, another halfway from the rind to the center, and a third at the center; or the trier may be run from the edge of the cheese into the center.

When the sample is taken it should be chopped as fine as wheat kernels. If the particles are much larger, they are likely to be burned by the acid before being dissolved. The fat would be locked up in the burned particles, and as a result the test would be too low.

The cheese can be chopped fine by placing the sample in a glass bottle and cutting it with a case knife. When cut fine, 3 or 4 grams of the cheese should be weighed into a cream bottle. A small quantity is used because so much acid is required in order to dissolve the curd. The sample is then made up to approximately 18 grams by adding warm or hot water. The warm water tends to soften the curd. Acid is then added, a little at a time, with continual shaking until the curd is entirely dissolved. It frequently takes slightly more than the normal quantity of acid to dissolve the curd; if the sample is old and dry, the operator must use his own judgment in regard to the proper quantity of acid. From this point the cheese is tested the same as is whole milk, except that glymol should be used in reading the completed test.

CHEESE-MOISTURE TEST (Troy)

The following apparatus is required: drying flask; jacketed cup for heating flask; thermometer; tripod; alcohol lamp; scales.

The cheese sample should be taken by drawing two or three plugs with a trier. After closing the openings in the cheese with the outer half inch of the plugs, cut the remainder of the plugs into pieces as small or smaller than kernels of wheat, or a representative wedge-shaped piece of the cheese cut up in a similar manner will serve as a sample. Mix the pieces of cheese together thoroughly and weigh 5 grams into the drying flask. Place the flask in the heating cup. The oil or fat in the heating cup should be at a temperature of 145° C. when the flask is placed in the cup, and it should be held at that temperature for 50 minutes. The flask is then removed, covered, allowed to cool, and then weighed. The loss in weight divided by the weight of cheese taken gives the percentage of moisture.

The heating cup is double walled, made of copper, and is about five inches tall. There is a space of about three-fourths of an inch between the walls and bottoms which is filled to within one inch of the top with tallow. The inner walls form a cup for holding the flask, and are supported by means of the rim, which is bent outward to form a cover that fits down over the top of the outer walls. An opening in this cover serves for filling the space between the walls with melted tallow and also for holding a thermometer. Several hundred tests may be made without renewing the tallow.

When ready to heat the cup, place it on the tripod over the alcohol lamp. Insert the thermometer through the opening in the cover until its bulb is just covered with the melted tallow. The thermometer should not touch the bottom. It may be held in place with a piece of cork also placed in the opening. A flame about an inch tall and half an inch in diameter will

give about the right temperature. The temperature may be adjusted by bringing the flame up against the cup or by lowering it as the case demands. The double-walled cup containing the tallow between the walls should be beating while the operator is preparing the cheese sample. When the temperature reaches 145° C., the flask containing the cheese is put in place. If the temperature rises a few degrees higher during the test, it will do no harm if it is soon lowered to the proper point.

The drying flask is so shaped that particles of cheese will not spatter out during the drying process. The thermometer should register temperature changes up to 200° C.; then, if it should become overheated by accident, it would not break so soon. The small tripod and alcohol lamp and thermometer can be secured from any concern supplying chemical apparatus. Any scales like a butter-moisture scales that will weigh accurately to one-tenth of a gram will serve for weighing out the 5-gram sample.

The same apparatus may be used for determining the moisture in butter, the only difference between the two operations being that in testing butter for moisture, 10 grams of butter are taken in place of 5 grams as in testing cheese.

TEST FOR CASEIN IN MILK (Adapted from Hart [Wis. Bul. 156])

This method makes use of a specially designed test bottle by which the percentage of casein can be read directly (see Fig. 58).

Each division of the scale represents .1 c.c. and .2 per cent of casein where 5 c.c. equivalent to 5.15 grams of milk are used in the test, assuming the specific gravity of normal cow's milk as 1.030. The graduations extend from zero to 10 per cent. This is amply sufficient for all normal milks. The 10 per cent mark represented on the scale should correspond to exactly 5 c.c.

Two c.c. of chloroform fairly accurately measured are placed in the tubes. It is probably better to deliver the chloroform from a burette than to attempt to draw it up in a pipette. On top of the chloroform are added approximately 20 c.c. of the 0.25 per cent solution of acetic acid. The temperature of the acetic acid solution should be as near 70° F. as is practicable. A low temperature tends to give a high reading, while a high temperature depresses the volume of the casein. Five c.c. of milk, accurately measured, are next introduced into the tube; every precaution should be taken to have the sample represent as nearly as possible the whole lot of milk from which it is taken. The temperature of the milk should be from 65° to 75° F. After the introduction of the milk the thumb is placed over the neck of the tube, the tube inverted by rotating the hand in order to bring the chloroform down into the barren part of the tube, and the whole then shaken with reasonable vigor for 15 to 20 seconds. This should be timed by the watch. The purpose of shaking is to break up the chloroform mass and bring it into intimate contact with the fat globules, thereby dissolving them. If the shaking is continued for too long a time, a partial emulsion is effected, with a tendency toward a high reading and a very ragged reading line between the chloroform and the casein. After shaking, the tubes can be placed immediately in the centrifuge, or when a great number are being run, can be allowed to stand until the same process has been repeated on the others. It is better to prepare all the tubes with the chloroform acetic acid mixture, then introduce the milk and proceed with the shaking on the whole series, than to prepare each tube singly. The

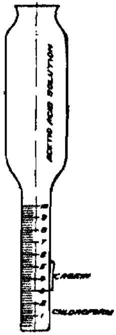


FIG. 58.—Special test bottle *for the Hart casein* test.

reason for this is that too long a contact with chloroform may vitiate the results. No harm, however, results if the tubes after shaking and before centrifuging are allowed to stand 15 to 30 minutes, but longer standing than this can introduce an error. The tubes are next placed in the centrifuge with the revolving wheel 15 inches in diameter when the tubes stand extended. The machine should be run closed. After the speed of 2000 revolutions a minute has been attained, the test is run seven and one-half to eight minutes. A slight variation from the above speed will not introduce a serious mistake. A range of 50 revolutions on either side is allowable. The time should be regulated by a watch.

As soon as the tubes have been properly whirled they should be removed and placed in the rack, which supports them in an upright position. If properly worked, the casein will rest as a sharply defined white mass above the chloroform now holding the fat in solution, while above the casein will be a water-clear solution of the other milk solids. The tubes should be allowed to stand at least ten minutes before reading. This is imperative. After suddenly relinquishing the centrifugal force from the casein pellets, a proper time is necessary for them to regain a constant volume. This requires at least ten minutes. After the first ten minutes practically no change in volume results, even on standing 24 hours at room temperature.

Measuring the casein.

Hold the tube in a perpendicular position with the scale on a level with the eye. Observe the divisions which mark the highest and the lowest limits of casein. The difference between them gives directly the per cent of casein in the milk. Readings can easily be taken to half divisions or one-tenth of a per cent, and with care and practice even to five-hundredths of a per cent. The lines of division between the casein and chloroform on the bottom and the dilute acetic acid solution on the top are usually straight lines, and no doubt need arise concern-

ing the readings. Occasionally, for reason of improper centering of the tube during the centrifugal process the casein may not be perfectly horizontal with the bottom of the tube; in such cases the readings should be taken only on the side of the tube that is graduated. Occasionally a film sharp in outline and clearly distinguishable projects below the layer of casein proper. If this has occurred, the space occupied by this film should not be included in the reading. This film is most often due to too vigorous shaking and can be avoided.

MODIFICATIONS OF THE CHEDDAR PROCESS

There are several modifications of the method of making cheddar cheese which are in use in the different cheese-making districts, the more important being the use of skimmed or partly skimmed milk, the soaking of the curd, the use of pasteurized milk and flavoring the cheese with sage.

Skimmed-milk cheese.

In some of the cheese-making sections, cheese made from milk from which a part or all of the fat has been removed, constitutes an important part of the cheese industry. The desirability of making this type of cheese will depend on local conditions, especially the market for butter-fat for use as sweet cream or for butter-making. While the removal of a portion or all of the fat from the whole milk materially affects the quality and composition of the finished cheese, by modifying the ordinary method of making, a very edible cheese can be produced having a clean, pleasant flavor and containing a considerable amount of food nutrients. Many states have discouraged the manufacture of cheese from skimmed milk because of the difficulty of protecting the consumer against purchasing it as full milk cheese. While cheese of this kind may be perfectly wholesome and a good food, it does not have the same food value as whole milk cheese, and the price paid by the consumer should

be correspondingly less. To offset the removal of the milk-fat, it is necessary to incorporate a high percentage of moisture in skimmed-milk cheese in order to prevent its being too dry and hard. When properly made and cured, this type of cheese will develop good flavor and texture even though it lacks the richness and quality of the whole milk cheese.

The effect of skimming on the composition of the cheese is given by Van Slyke and Publow [1] as follows:

Per Cent of Fat in Cheese	Per Cent of Proteins in Cheese	Percentage of Cheese-solids in Form of Fat	Ratio of Fat to Proteins in Cheese
			Fat : Proteins
(1) 35.1 . . .	22.7	55.7	1 : 0.65
(2) 33.3 . . .	24.5	53.0	1 : 0.74
(3) 31.1 . . .	26.7	49.4	1 : 0.86
(4) 25.2 . . .	32.6	40.0	1 : 1.30
(5) 16.1 . . .	41.7	25.5	1 : 2.60
(6) 2.3 . . .	55.5	3.7	1 : 24.00

Soaked curd cheese.

This modification of the cheddar process has for its purpose the incorporation of an increased amount of moisture in order to increase the yield of cheese, the removal of abnormal flavors, and the acquisition of a soft texture. Under certain conditions, the bad effects of gas and undesirable bacteria in milk may be partly removed by washing with cold water. This process, however, is apt to remove a portion of the milk solids, together with the lactic acid. The removal of the milk-sugar checks the development of the lactic-acid-forming bacteria and interferes with the proper ripening of the cheese. Cheese made by this process is liable to be weak in body and texture and does not keep well in storage.

[1] Science and Practice of Cheesemaking, Orange Judd Co.

Cheese from pasteurized milk.

While the practice of pasteurizing milk for market purposes and of cream for butter-making has become quite general as a means of protecting the consumer against disease organisms, the pasteurizing of milk for cheddar cheese-making has not been general, because of the effect of the heating process on the coagulation of the casein. When milk is heated to the pasteurizing temperature, certain changes take place in the milk salts which prevent the coagulating action of the rennet. This process of making cheddar cheese has been carefully studied at the Dairy Department of the University of Wisconsin,[1] and certain modifications of the regular cheddar process have been worked out which are claimed to give cheese of very satisfactory quality.

These modifications are described by Sammis and Bruhn as follows:

"The difficulties met with hitherto in making American cheddar cheese from pasteurized milk are:

"First. That heated milk coagulates poorly with rennet; and

"Second. The curd when obtained does not expel moisture precisely as a raw-milk curd does, and this effect is more marked the higher the temperature of pasteurization. The quality and behavior of pasteurized-milk curd suggest that it lacks the acid which is normally produced in raw-milk curds by the action of bacteria on milk-sugar.

"The first of these difficulties, but not the second, can be overcome by adding calcium-chlorid solution to pasteurized milk. This method has been tried experimentally, but is not recommended for use in American cheese factories. Both difficulties, however, are overcome by adding an acid, preferably hydrochloric, to the pasteurized milk. Hydrochloric acid

[1] Wisconsin Research Bulletin No. 27 and Bul. 165.

is normally present in the human stomach during the process of digestion in larger proportions than that added to milk in this process of cheese-making. Further, 95 per cent of the added acid passes out of the cheese with the whey during the process of manufacture. On this account no objection can be made on sanitary grounds to the use of this acid in the manner and for the purposes described.

"Among different lots of cheese, part of which was made with hydrochloric acid and part with calcium chlorid added to portions of the same milk after pasteurization, those made with acid were found to be more uniform in moisture-content and superior both in flavor and texture to those made with calcium chlorid. The losses of fat in the whey are reduced by the use of the acid. Pasteurization and acidulation of milk for cheese-making appear to be complementary processes. Used together, they furnish a means for bringing milk daily into uniform condition both as to acidity and bacterial content for cheese-making purposes.

"The acidulation of milk with hydrochloric acid after pasteurization is accomplished without difficulty or danger of curdling by running a small stream of the acid, of normal concentration, into the cooled milk as it flows from the continuous pasteurizer into the cheese vat. One lb. of normal-strength acid is sufficient to raise 100 lb. of milk from 0.16 per cent to 0.25 per cent acidity (calculated as per cent of lactic acid). The amount of acid needed each day to bring the milk up to 0.25 per cent acidity is read from a table or calculated from the weight of the milk and its acidity, determined by the use of Mann's acid test (titration with tenth-normal sodium hydrate and phenolphthalein). The preparation of standard-strength acid in carboy lots for this work and the acidulation of milk present no great difficulty to any one who is able to handle Mann's acid test correctly.

"After the milk is pasteurized and acidulated three-fourths

per cent of first-class starter is added and the vat is heated to 85°. It is set with rennet, using 2 oz. of rennet to 1000 lb. of milk, so that the milk begins to curdle in 7 minutes and is cut with three-eighth inch knives in 25 minutes. All portions of the work after adding rennet are carried out in an unvarying routine manner, according to a fixed-time schedule every day. As soon as the rennet has been added the cheese-maker is able to calculate the exact time of day when each of the succeeding operations should be performed, and the work of making the cheese is thus simplified and systematized.

"The average loss of fat in whey from pasteurized-acidulated milk is about 0.17 per cent measured at the time the whey is drawn from the vat. This is less than half the loss in average factories using raw milk. The total loss of fat in whey and drippings from vat and press, using pasteurized milk with acid, averaged 1.58 per cent of the weight of the cheese, or less than one-half of the usual loss in handling raw milk.

"In addition to this saving of fat, it is found that a somewhat larger proportion of moisture can be incorporated in pasteurized-milk cheese than in ordinary cheese, without damage to the quality. The gain in the yield of pasteurized-milk cheese is due partly to fat and partly to moisture.

"Scores and criticisms made by competent cheese judges show that the pasteurized-milk cheese varies less in quality and averages better by 3.7 points of total score than the raw-milk cheese made from portions of the same milk supply. In 96 per cent of all cases the pasteurized-milk cheese scored higher than the raw-milk cheese.

"Duplicate sets of cheese were cured at New Orleans for one month at 70° to 83° (monthly average figures during the summer), and here the raw milk lost more in weight than the pasteurized, so that the average gain in yield of pasteurized over raw rose to 6.21 per cent. From other cheese cured at Madison on tin pans in a warm room, it was learned that the

raw-milk cheese lost considerable amounts of fat at 75° to 85° while the pasteurized-milk cheese lost none.

"Storage for a month at an average temperature of 75° to 80° at New Orleans is not recommended for any cheese, yet it was found that pasteurized-milk cheese averaged 3 to 8 points better in total score after such storage than raw-milk cheese.

"Since pasteurized-milk cheese can be cured without injury at 70°, it is likely that in most cases the expense of cold storage for this cheese can be avoided.

"Pasteurized-milk cheese can be put into cold storage at 34° at the age of one week and possibly earlier without injury. The earlier the cheese can be put in storage, if this is done at all, the greater will be the gain in yield by the new process.

"Pasteurized-milk cheese was sold to about fifty dealers, both wholesale and retail, in various large cities from New York to San Francisco. The cheese sold readily for the ruling market prices and often above. Very few dealers offered any objections to them and several wished to buy them regularly. A good many were sold throughout the South by dealers. In general, the cheese passed through the market without exciting special comment, selling for full price and giving satisfaction. They were not labeled or marked except with a number for purposes of identification. There appears to be no reason why pasteurized-milk cheese cannot be sold regularly in any market with entire satisfaction, excepting possibly to the limited trade that demands very high-flavored cheese.

"The new process should interest the farmer because of the increased yield and the avoidance of the usual losses in yield and quality of cheese due to defective milk. It should interest the cheese-maker because the process of making is systematized to such a degree that it is conducted on a fixed-time schedule for all operations. It should interest the dealer because the cheese is more uniform in quality and there is less need for cold

storage in curing. Finally, the cheese should interest the consumer, because it is more uniform in flavor than most of the cheese to be found on retail counters and because it is made from pasteurized milk and is therefore a more sanitary product than ordinary American cheese made from raw milk."

Sage cheese.

Sage cheese is another modification of the cheddar type. It may be made in any form or size. Its distinguishing characteristic is that it is flavored with sage either by using ground-up sage leaves or sage extract. If the ground leaves are used, they are mixed with the curd before it is placed in the press. *This gives the cheese a mottled or speckled appearance* and the sage flavor permeates the entire cheese during the ripening period. When the extract is used, it is sprayed over the curd with an atomizer after it has been milled. In order to give the cheese a green mottled appearance, a small part of the milk is set in a vat by itself and colored green with some vegetable juice such as green corn or spinach. After the curd has been cut, the colored curd is mixed with the remainder of the make, *giving the finished cheese the desired green, mottled appearance.* In some markets this variety of cheese is popular and commands a price somewhat higher than the regular cheddar.

DEFECTS IN AMERICAN CHEDDAR CHEESE (Publow)[1]

The purpose of this discussion is to provide a ready reference that will aid New York manufacturers of American cheddar cheese to prevent or remedy the most common defects in their product. In order to understand and to be able intelligently to remedy or prevent defects in cheese, it is necessary to know just what the underlying causes are. If a correct diagnosis is made, then the treatment is usually easy.

[1] C. U. Bul. 257.

I. Defects in Flavor

A. Acid Flavors.

Indicated by a sour smell and taste.

Cause.

Over-development of acid during the manufacturing period, which is commonly due to one or more of the following:

(1) Ripening the milk too much before adding the rennet.

(2) The use of too much starter.

(3) Failure to firm the curd before removing the whey.

How to prevent.

(1) Have less acid in the milk before adding the rennet. Sour milk should not be accepted from any patron.

(2) Use less starter. Generally one-half per cent to two per cent is sufficient.

(3) Add the rennet early enough so that the curd will become firm in the whey before developing the desired amount of acid.

Remedy.

Refer to the treatment explained under remedy for acid texture (p. 332).

B. "Off" Flavors.

Flavors that are not clean. When in an advanced stage, cheese so affected are called "stinkers."

Cause.

Undesirable bacteria which gain entrance to the milk or to the curd some time during the manufacturing process, commonly due to:

(1) Failure of patrons to wash thoroughly and scald all cans and utensils coming in contact with the milk. This is particularly true of cans in which whey is brought from the factory.

(2) Careless milking in unclean places.

(3) Allowing the milk to become exposed after milking, in places where the air is impure.

(4) Keeping the milk at too high temperature.

(5) Using an unclean strainer either at the farm or the cheese factory.

(6) Using utensils in the factory that have not been thoroughly cleaned and scalded.

(7) Using badly flavored starters.

(8) Using impure water for diluting rennet.

(9) Soaking curd in impure water after milling. This causes lack of flavor and later on bad flavor.

(10) Using tainted rennet or salt.
(11) Ripening cheese at temperatures above 60° Fahr.

How to prevent.

By absolute cleanliness in the production and handling of the milk and throughout the whole manufacturing process.

(1) All utensils, especially the milk strainer, should be thoroughly washed with warm water and washing powder, then scalded with live steam.
(2) Milking should be done in clean places, where dust, cobwebs and flies are not found.
(3) Milk should be cooled to at least 60° and better 50° Fahr., immediately after being drawn from the cow.
(4) Tainted milk should not be taken from any patron. If uncertain of the source of tainted milk or curds, use the fermentation test on each patron's milk.
(5) By the use of clean flavored starter.
(6) Impure or bad smelling water should not be used.
(7) Screens should be on the doors and windows to prevent the entrance of flies.
(8) Curds should not be soaked in impure water after milling.

Remedy.

(1) Firm the curd a little more than usual in the whey by raising the temperature.
(2) Develop a little more acid before removing all the whey.
(3) Mill early and expose well to fresh air by stirring for some time immediately after. Excellent results can be secured at this time because each small piece of curd has four freshly cut surfaces which permit the gases and odors to escape.
(4) Increase the amount of salt in extremely bad cases.
(5) Ripen the cheese at low temperatures.

C. Fruity Flavors.

Sweet flavors having an odor like that of ripe fruits, such as pineapple, raspberry, strawberry, etc. To the taste they are not pleasant and somewhat sickening.

Cause.

(1) Bacteria carried into the milk by dirt.
(2) Transporting both milk and whey in the same cans that have not been properly cleansed.
(3) Exposing milk to the air of hog-pens where whey is fed.

How to prevent.

(1) Cans used for delivering milk should not carry whey unless they are emptied and thoroughly cleansed immediately after arriving back from the factory.

(2) All whey should be pasteurized at the factories. This would not only greatly reduce the source of badly flavored milk, but it would eliminate the danger of transmission of tuberculosis through the whey.
(3) The whey tanks should be cleaned and scalded at least twice a week. A steel tank has the following advantages: It is more durable than wood or cement, does not leak, does not absorb the whey, is easily cleaned, and is cheaper in the long run.
(4) Use a clean flavored commercial starter.

Remedy.

(1) Firm the curds a little more in the whey by raising the temperature.
(2) Develop a little more acid.
(3) Air the curd well after milling.
(4) In extreme cases use more salt.

D. Bitter Flavors.

Indicated by a bitter taste and a "weedy" odor.

Cause.

(1) Bacteria and yeasts.
(2) Allowing cows to wade in and drink from stagnant pools.
(3) Using rusted milk cans or utensils.
(4) Using old starters that have developed too much acid.
(5) Using milk delivered in cans in which sour whey from dirty tanks is returned.

How to prevent.

(1) Milk should be cooled to at least 60° and better to 50° Fahr. immediately after milking.
(2) Rusted cans or utensils of any kind should not carry milk.
(3) Cows should have good water only.
(4) Clean flavored starters only should be used.

Remedy.

(1) Very little acid should be developed before removing the whey.
(2) Firm the curd more than usual. Heat it higher in the whey and stir it dryer when removing the whey.
(3) Mill early and expose well to fresh air by stirring.
(4) In extreme cases use more salt.

E. Food Flavors.

Those characteristic of the foods eaten by a cow. A food flavor can be distinguished from one produced by bacteria in that a bacterial flavor usually gets worse as the milk or cheese ages, while a food flavor generally decreases with age.

Cause.

(1) Such foods as turnips, onions, leeks, weeds, garlic, rape, decayed silage and clover.

(2) Exposing milk in an atmosphere where any of these are exposed.

(3) Storing milk in cellars where decayed vegetables are present.

How to prevent.

(1) Foods that impart any objectionable flavor to milk should not be fed or made accessible to the cow.

(2) Use a good commercial starter.

Remedy.

(1) Heat the curd several degrees higher in the whey. The high temperature helps to drive off the volatile flavors.

(2) Air the curd well, especially after milling.

(3) Ripen the cheese at a low temperature.

II. Defects in Texture and Body

F. Dry Textures.

Cheese that are too firm, mealy, rubbery or corky.

Cause.

Lack of moisture or butter-fat or both, produced by

(1) Removing part of the butter-fat from the milk.

(2) Too high heating in the whey.

(3) Heating too long.

(4) Too much stirring at the time of removing the whey.

(5) Using too much salt.

(6) Curing cheese in an atmosphere that is too dry or too hot.

A "high cooked" cheese is rubbery or corky; one that has been stirred too dry is mealy or sandy; and one dry from excess of salt tastes salty. This is a convenient way of determining the canse of such defects.

How to prevent.

(1) All the milk-fat should be retained in the cheese as far as possible.

(2) The lower the temperature used for heating and still have the curd firm enough, the better will be the texture of the cheese.

(3) Be absolutely sure of the correctness of thermometers.

(4) Study the moisture content and the amount of stirring and salt required.

Remedy.

(1) Pile dry curds higher.

(2) Keep the air moist by placing hot water in the vat.

(3) Do not mill dry curds early.
(4) A dry curd can be made mellow by soaking in pure cold water after milling, but the cheese will not have a good keeping quality.
(6) Paraffin the cheese as soon as possible.
(7) Ripen the cheese in a cool room where the atmosphere contains at least eighty per cent moisture.

G. Acid Textures.

These may be either dry or moist, but in either case they are of a mealy or sandy character. They have a sour taste.

Cause.
(1) Ripening the milk too much before adding the rennet.
(2) The development of too much acid during the manufacture, especially before the whey is removed.
(3) The great majority of acid or sour cheese are caused, not by the giving of too much acid, but by not having the curd firmed in the whey when the acid has developed.
(4) Using large starters.

How to prevent.
(1) No sour milk or milk containing more than twenty-six hundredths of one per cent acid should be taken from any patron.
(2) Add the rennet early enough so that the curd may be firmed in the whey by the time the acid has developed sufficiently.
(3) Do not use too much starter.
(4) Keep the development of acid under control by controlling the moisture.

Remedy.
When it is absolutely necessary to make sour milk into cheese it should be done in the following manner:
(1) Heat the milk not above 80° Fahr.
(2) Use an extra amount of rennet.
(3) Cut the curd into smaller pieces.
(4) Heat higher. The degree of heat will depend on the rapidity with which the acid is developing. Most fast working curds contract rapidly so the heating can be hurried.
(5) As soon as possible after heating the whey should be run down to the level of the curd. This greatly facilitates stirring and firming of the curd, and if more than one vat is being used, time is saved when the remainder of the whey is to be removed. If by this time the curd is not firm and shows too much acid, a sour cheese can be prevented by,

(6) Removing the whey and putting on pure water at a temperature of 102° Fahr. The amount of water used and the time it is left on will depend on the amount of acid in the curd. In extreme cases it may be necessary to use a second quantity of water. As soon as the curd becomes firmed in the water and the acid reduced to a normal amount, the water should be removed. The curd should then be treated like an ordinary sweet one. This method is not to be confounded with the "soaked curd" process, which is different.

(7) If after milling curds are sour, they can be improved by a washing in pure water at 80° Fahr. This resembles the "soaked curd" process, and as a rule the cheese have not a good keeping quality. However, it is much better than allowing the cheese to sour, and should be used in extreme cases.

Use an extra amount of salt after washing.

H. Loose or Open Texture.

Also called soft or weak bodied. These cheese are very soft and full of holes. Such defects are noticed more when found in export cheese, as for that trade a close boring cheese is demanded.

Cause.

(1) Developing too little acid and retaining too much moisture.
(2) Putting curd to press at too high a temperature.
(3) Lack of pressing.
(4) Soaking curd in water after milling.

How to prevent.

(1) Have at least .24 per cent acid in whey running from the curd after it is piled for cheddaring.
(2) The curd should be cooled to at least 80° Fahr. before pressing. This can be hastened by running cold water around the outside of the vat lining.
(3) Two days pressing is much better than one. A continuous pressure is of more value than a short heavy pressure.
(4) Curd should not be soaked in water.

Remedy.

(1) Open cheese can be closed up considerably by repressing.
(2) Ripen in a cool atmosphere.

I. Yeasty Cheese.

Indicated in the green cheese by small white pin holes which later enlarge into fish-eye-like slits. The flavor is usually bitter. Colored cheese when affected usually become mottled. A bitter flavor can usually be detected

in the milk and curd. The curd may exhibit peculiar characteristics. It is usually difficult to firm in the whey. The acid appears to develop slowly at first, but very fast from the time the whey is started till it is all removed. After milling the curd will become "mushy" if it is at all moist, and the whey running from the curd may show less acid than it did before milling. The curd is usually very slow to shrink up before salting. In extreme cases the whey tank may boil as though heated by fire.

Cause.

(1) Yeasts. These enter the milk on hay dust and from leaves of trees. They grow and multiply most rapidly when milk is kept at temperatures above 60° Fahr.

(2) Returning sour or unpasteurized whey in milk cans aggravates the trouble.

How to prevent.

(1) Milk should be kept free from dust, and should be cooled to at least 60° Fahr. as soon as milked.

(2) Use a clean commercial starter.

(3) The whey should be pasteurized and the tanks cleaned every day.

(4) If the trouble is already present, the whey tank, all factory utensils and all patrons' milk cans and utensils should be thoroughly cleaned and scalded.

Remedy.

(1) Add the rennet early.

(2) Heat curd in the whey a few degrees higher.

(3) Draw off the whey with as little acid as is practical, but have the curd well firmed first.

(4) Do not pile the curd high unless gas is present.

(5) If gas is present, more acid must be developed at dipping, but the curd should be stirred dryer.

(6) After milling, if the curd tends to become mushy, one-half the salt should be applied. When the curd is well shrunken, apply the other half.

J. Gassy Cheese.

Indicated by the presence of pin holes. They usually have a bad flavor, are spongy, and the curd may float on the whey in the early stage of manufacture.

Cause.

(1) Gassy milk produced by bacteria which are carried in by dirt.

(2) Gassy starters.

How to prevent.

(1) Gassy milk should not be accepted from any patron.

(2) Gassy starters should not be used.

Remedy.

(1) *If it is known that the milk is gassy, use a safe amount of* clean commercial starter.

(2) Ripen the milk a trifle more before adding the rennet.

(3) After cutting, stir the curd till whey around it shows at least 15 per cent acid before heating.

(4) Heat slowly. Take from thirty minutes to one hour.

(5) Care should be taken to not have the curd too firm in the whey before the acid starts. An acidimeter is a valuable guide at this time.

(6) A little more acid should be allowed to develop before removing the whey. About .32 per cent after the whey is all off is sufficient.

(7) Should the curd float, remove enough whey to bring the curd to the bottom of the vat.

(8) Pile gassy curds before and after milling.

(9) After milling, the curd should be thoroughly stirred and aired before piling. The pressure causes the small *pieces to become very thin. After the piling and airing* have been repeated a few times at intervals of fifteen to twenty minutes, the gases should have nearly all escaped. The pin holes will then have become flattened and present a "dead" appearance.

(10) The whey running from the curd at this time should show 1.2 per cent acid.

(11) Cool curd well before hooping.

(12) Press for two days if possible.

(13) Ripen in a cool place.

K. Greasy Texture.

Indicated by free butter located in mechanical holes in the cheese. The cheese surfaces are usually greasy. This condition is most common in the springtime.

Cause.

(1) Allowing milk to become too old before manufacturing. In factories that do not take milk on Sunday the trouble is always greatest on Monday.

(2) Heating milk too high or too long before adding rennet.

(3) Handling curd too roughly.

(4) Piling curd too much.

(5) Maturing curd at high temperature.

(6) Using a mill that bruises the curd.

(7) Ripening cheese in hot curing rooms.

How to prevent.

(1) Make up the milk daily.

(2) Cut and stir the curd very carefully while soft.

(3) Do not pile curd more than two layers deep.

(4) Do not heat milk or curd too high. Be sure of thermometers.

(5) Use a mill that cuts the curd without squeezing the fat from it. The knives should move against the curd and not the curd against the knives.

(6) Apply the salt soon after milling and mature curd in the salt.

(7) Ripen cheese in a cool room.

Remedy.

(1) Rinse the curd with pure water at 90° Fahr. before salting. Then use a trifle more salt.

(2) Cool curd before hooping.

(3) Use large clean press cloths to insure a good rind formation.

(4) Use sufficient hot water at time of dressing the cheese.

III. Defects in Color

L. Pale or Acid Cut Color.

This term explains itself.

Cause.

(1) The development of too much acid which bleaches or cuts the color from the curd.

(2) Failure to firm the curd early enough in the whey.

(3) Using large starters.

(4) Using poor color.

How to prevent.

(1) Have the curd firmed in the whey before the acid has developed to more than eighteen one-hundredths of one per cent.

(2) Cheese should be colored to suit the market for which they are intended.

Remedy.

(1) The best place and time to produce a bright even color in the curd is while the whey is being removed. From the time the whey has reached the level of the curd till it is all removed, the curd should be well stirred. The color can be seen to develop rapidly during this handling.

(2) Allow the curd to stand some time after salting before hooping.

M. Mottled Color.

An uneven color, most noticeable in colored cheese.

Cause.

(1) An uneven development of acid and moisture in the curd.
(2) Uneven cutting, leading to an uneven contraction of the curd when heated in the whey.
(3) Neglecting to strain the starter when lumpy.
(4) Adding starter after color.
(5) Uneven piling and maturing of curds.
(6) Use of poor color.
(7) Mixing curds from different vats.
(8) Lumpy conditions of the curd at time of removing the whey or when salt is applied.
(9) Adding old curd.
(10) Yeasts. When due to these the mottling increases with the age of the cheese.

How to prevent.

(1) By uniform cutting, heating and stirring. This is facilitated by the use of a five-sixteenths inch perpendicular wire knife, and a five-eighths inch horizontal steel knife.
(2) Each particle of curd should be kept separated from the others while being heated.
(3) Starter should always be strained.
(4) Starter should be added before the color.
(5) Curds from different vats should not be mixed.
(6) Old curd should be placed in the vat about fifteen minutes before the whey is removed.

Remedy.

When curds are badly mottled there is no remedy that will make the color uniform. In some instances the color will become more even as the cheese ages.

N. Seamy Color.

A condition in which the outline of each piece of curd can be easily seen in the cheese. The uniting surfaces are marked by a pale line.

Cause.

(1) Greasy curds, which prevent an even absorption of salt.
(2) Impure salt.

How to prevent.

(1) If curds are very greasy they should be rinsed off with pure water at 90° Fahr. just before salting.
(2) Only high grade salt should be used.

Remedy.

Prevention.

O. Rusty Spots.

Red spots resembling rust, and located usually where two pieces of curd have pressed together.

Most noticeable in white cheese.

Cause.

(1) *Bacillus rudensis*, which gains entrance to the milk or curd.

(2) Unsanitary buildings and surroundings. When whey leaks through the factory floor, the red material formed by these bacteria may develop. It may then be carried into the factory by wind or flies. Once in the factory every utensil used in the manufacturing soon becomes infected and the trouble increases.

How to prevent.

(1) Keep everything used in the factory absolutely clean.

(2) Do not allow the factory floor to leak. Cement floors are most sanitary.

(3) Keep the drain and drain pipes clean.

(4) Use screen doors and windows during fly time.

Remedy.

(1) The only way to get rid of this trouble is by a thorough cleaning and disinfecting of the factory surroundings and all utensils.

(2) The starter, if one is used, should be renewed.

How to clean and disinfect.

(1) Wash all utensils with a brush, hot water, and washing powder, and put them into the large milk vat.

(2) Put a cover over the vat and turn live steam into it.

(3) Steam the utensils for at least one-half hour.

(4) If the drains are dirty, clean them with hot water and washing powder. Then steam them for at least twenty minutes.

(5) If the ground surrounding or under the factory is infected, have it covered with lime or fresh earth.

(6) The inside walls, cheese shelves and all wood work should be washed with a hot solution of bichlorid of mercury. This is made by dissolving seven and one-half grains of bichlorid of mercury in one pint of water. Apply this solution with a brush or broom, as *it is a poison.*

IV. Defects in Finish

Anything that detracts from the appearance of a cheese is a defect. As a rule it is a defect due to carelessness on the part of the maker.

P. Unclean Surfaces.

Cause.

(1) Placing cheese on unclean or molded shelves in the curing room.

(2) Using dirty hoops or handling the cheese with dirty hands.

How to prevent.

(1) Wash the shelves after each shipment of cheese leaves the factory. Use a brush, hot water, and some good washing powder that will remove grease. Place them in the sunlight to dry.

(2) Cheese hoops should be clean. So should the hands of the maker.

Q. Cracked Rinds.

Openings in the side or ends of the cheese. They are unsightly and allow the entrance of molds, flies, etc.

Cause.

(1) Too much acid.
(2) Greasy curds.
(3) Use of hard press cloths.
(4) Lack of pressing.
(5) Wrinkled bandages.
(6) Too dry an atmosphere in curing room.

How to prevent.

(1) Avoid excess acid. (See remedy for acid texture.)
(2) Rinse greasy curds with water at 90° Fahr. before salting.
(3) Press cloths can be softened by soaking in a weak solution of sulphuric acid.
(4) Press cheese longer before dressing.
(5) Curing room atmosphere should register eighty per cent moisture.

Remedy.

(1) Repress the cheese. If this fails,
(2) Paraffin the cheese.

R. Moldy Surfaces.

The formation may be of several colors.

Cause.

The growth of moulds is due to
(1) Too much moisture in the air.
(2) Atmosphere too warm.
(3) Not enough circulation of air.
(4) Lack of cleanliness in curing room.

How to prevent.

(1) Curing rooms should be so equipped that the temperature and moisture can be controlled.
(2) Good circulation of air should be provided.
(3) Curing room should be kept clean.

Remedy.

(1) By spraying cheese with ten per cent formalin.
(2) By burning sulfur, three pounds to one thousand cubic feet of air.
(3) By washing the ceilings, walls, shelves and all wood work with a hot solution of bichlorid of mercury (*poisonous*) made by dissolving seven and one-half grains in a pint of water, and then washing with clear water.
(4) By whitewashing the walls and ceilings.

V. Facts a Cheese-maker Should Remember

The finished cheese can be no better than the milk from which it is made.

Every cheese-maker should be familiar with the use of the acidimeter and the fermentation test.

The cheese factory should be a center of rural dairy education.

The maker should be qualified to teach his patrons.

If the factory building is neatly painted, if the surroundings are tidy, and if the maker himself has a good appearance, it will be easier to induce the patrons to furnish better milk.

It will be of much greater value to both the cheese-maker, the patron and the consumer, if in the future more attention is given to the improvement of quality rather than quantity.

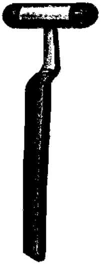


Fig. 59. — A cheese trier for sampling cheese.

QUALITY AND JUDGING OF CHEESE

A well-ripened cheese of good quality should have a clean, pronounced, pleasant flavor and aroma, and the body should be smooth and waxy. In scoring cheese the quality is judged by drawing a cylindrical plug by means of a trier (see Fig. 59). In judging the quality of cheese, a score-card is used, as is the case with other dairy products. Various modifications of score-cards have been used, the following being a representative one.

CHEESE SCORE-CARD

Sample.................. *Date*..................

Score			Remarks
Flavor . .	50	......	
Body and Texture .	25	......	
Color . .	15	......	
Finish . .	10	......	
Total . .	100	......	

RECOMMENDATIONS: ....

....

....

....

....

....

Name of Judge..................

SUGGESTIVE TERMS

FLAVOR

Desirable

Clean Pleasant Aroma Nutty Flavor

Undesirable

DUE TO FARM CONDITIONS

Weedy Feedy Cowy Old Milk Bitter

DUE TO FACTORY CONDITIONS

Too much acid Too little acid

DUE TO EITHER FARM OR FACTORY CONDITIONS

Yeasty Fruity Fishy Rancid
Sour Bitter Sweet Tainted

BODY AND TEXTURE

Desirable

Smooth Waxy Silky Close

Undesirable

Pasty Greasy Curdy Mealy Lumpy
Corky Loose Gassy Yeasty
Acidy Sweet Watery Too dry

COLOR

Desirable

Uniform

Undesirable

Streaked Mottled Acid cut
White Specks Wavy Too high
Seamy Rust spots Too light

FINISH

Desirable

Clean surfaces Neat bandage Attractive

Undesirable

Wrinkled bandage Greasy
Unclean surfaces No end caps
Cracked rinds Uneven edges
Undesirable size

CHEESE RULES

OF THE

NEW YORK MERCANTILE EXCHANGE

Adopted May 4, 1915

RULE 1. At the first regular meeting of the Executive Committee in each year, the President shall appoint, subject to the approval of the Executive Committee, a Cheese Committee to consist of seven members of the Exchange, who are known as members of the cheese trade, to hold office until their successors are appointed. It shall be the duty of the Cheese Committee to formulate such rules and regulations as may be necessary for the government of transactions between members of the Exchange, and to revise the same as circumstances may require. Such rules and revisions shall be subject to the approval of the Executive Committee.

RULE 2. All transactions in cheese between members of the Exchange shall be governed by the following rules, but nothing therein shall be construed as interfering, in any way, with the rights of members to make such special contracts or conditions as they may desire.

RULE 3. If a sale is made from dock, or platform, or to arrive, the buyer shall assume the same relations toward the transportation line by which the cheese arrives, as the seller previously held as regards its removal from the place of delivery within the time granted by such lines for that purpose. Transactions between members of this Exchange shall be governed as follows: Any member negotiating for any lot of cheese belonging to another member, the price having been agreed upon, shall examine such lot of cheese within twenty-four (24) hours after such negotiation takes place. Failure to examine within said time releases the seller from any obligations to make delivery thereafter, if he so wishes.

RULE 4. In the absence of special agreement, all cheese purchased "in store" shall be understood as being ready and designed for immediate delivery, but the buyer shall have twenty-four hours in which to have the cheese inspected, and weight tested, and shall not be liable for the storage and insurance, if removed within two days.

RULE 5. When cheese are sold to arrive, or from depot or dock, the cheese must be accepted or rejected within six business hours after notice of actual arrival to buyer. Business hours shall be understood to be from 10 A.M. to 4 P.M. If buyer rejects the same, he shall state the reasons for rejection. Should the rejection be considered unfair, the seller shall at once notify the buyer that he declines to accept such rejection; and he may call for a Committee, which shall be composed of three members of the cheese trade; the seller choosing one, the

buyer one, and the third selected from the cheese trade by these two, or, they failing to agree, the third shall be appointed by the Chairman of the Committee on Cheese. The Examining Committee shall at once inspect the lot of cheese in dispute, sampling not less than five (5) per cent of each mark or factory, and they shall immediately give their decision in writing to both parties. Either party failing to abide by the decision of the Committee may be summoned by the other party before the Complaint Committee under Section 24 of the By-laws. The fees for each examination shall be six ($6) dollars, to be paid by the party adjudged to be in fault.

RULE 6. The weight of all cheese shall be tested by a regularly appointed official weigher, and his certificates shall accompany the document conveying the title of the property. Said official weigher to be appointed by the Committee on Cheese, subject to the approval of the Executive Committee.

RULE 7. The weigher's fee shall be twenty-five (25) cents per factory except where the owner requires more than ten (10) boxes be tested, in which case the fee shall be fifty (50) cents, which shall be paid by the seller.

RULE 8. Unless otherwise agreed upon in testing the weight of cheese, not less than five (5) boxes or more than ten (10) per cent of the whole lot shall be a test, and said test shall be considered good for three (3) business days, including day test is made.

RULE 9. In testing weights, all over and short weights shall be taken into the average on each particular factory. Single Daisies shall be tested on half pounds, Double Daisies and all other sizes on even pounds.

RULE 10. Where a lot of cheese is fonnd to test irregular in weights, either the buyer or seller may require the entire lot to be reweighed. The charge for same shall be three (3) cents per box.

RULE 11. Boxes of cheese which may be found largely at variance from original weights shall not enter into the average, but their weight shall be separately ascertained and certified to by the weigher.

RULE 12. Where sales are made, and the buyer finds damaged or sour cheese in excess of fifteen (15) per cent, it shall be optional with him to refuse or receive the remainder of the lot purchased. But, in the event of his accepting the remainder of the lot, the sour or damaged cheese shall revert to the seller.

RULE 13. The Committee on Cheese shall appoint, subject to the approval of the Executive Committee, a Cheese Inspector and also a Deputy Inspector, whose duties shall be, when called upon by members of the Exchange, to inspect the quality and condition of such lots of cheese as may be required and to render a certificate of such inspection. Where the cheese in the lots are reasonably uniform in quality, the examination of 10 per cent of the lot shall be considered sufficient,

but this shall not prevent the Inspector examining a larger percentage of the lot, when he deems it necessary. The fee for inspection shall be fifty (50) cents for lots consisting of fifty (50) boxes or less. Lots exceeding fifty (50) boxes shall be one cent per box, which shall be collected from the member ordering the inspection.

RULE 14. The Cheese Inspector's certificate shall be made to read as follows:

NEW YORK MERCANTILE EXCHANGE

Cheese Inspector's Certificate

Inspection No. . . . .

This is to certify that I have this day inspected for M . . . .
the following cheese, now located at . . . .
Factory and identification marks . . . .
Quantity in lot . . . . boxes
Quantity inspected . . . . boxes

and find as follows:
Flavor . . . .
Body and Texture . . . .
Color . . . .
Condition . . . .
Boxes . . . .
Grade . . . .
Inspection charges . . . .

. . . . *Inspector*

The certificate to have a blank margin of three inches at the bottom, for the purpose of inserting specifications of Institutions, also for cheese sold under the Call, so that the Inspector may certify that cheese inspected fill the requirements as specified.

RULE 15. The Inspector shall be supplied with a rubber stamp, to read as follows:

NEW YORK MERCANTILE EXCHANGE

OFFICIAL INSPECTION

Number . . . . Date . . . .

. . . . *Inspector*

and the Inspector shall brand one impression on both boxes and cheese.

RULE 16. The Weigher's Certificate shall be made to read as follows:

This is to certify that the following is the actual test of .... boxes, out of shipment of .... boxes

Factory Mark ....

Marked Weights ....

Actual Weights ....

Loss ....

Average Loss .... lb. on .... boxes

New York ....19...

.... *Weigher*

and the Cheese Rules numbered 6 to 11 inclusive be printed on the back thereof.

RULE 17. Members offering cheese for sale under the Call shall describe each lot, as to number of boxes, color, texture (open or close made), body, flavor, size, and how boxed, section where made, whether whole milks or skims and the average weight of each lot. Cheese sold under the Call to be accepted, or rejected, as a good delivery, or otherwise, based on the description given at the sale.

RULE 18. When cheese are sold under the Call, unless otherwise stated, they shall be ready for immediate shipment.

RULE 19. All cheese offered under the Call, with Inspector's Certificate attached, shall be accompanied by such Certificate and be accepted by the buyer unconditionally, provided the cheese are branded according to Rule 13.

RULE 20. When cheese are offered under the Call, without Inspector's Certificate, should the buyer not consider the cheese a good delivery, according to description by seller, he may notify the seller, and if the seller is unwilling to make another delivery, the buyer may call upon the Inspector to decide whether or not the delivery shall stand. If the Inspector decides it is a good delivery, the buyer shall accept the cheese. If the Inspector decides it is not a good delivery, then the seller shall have twenty-four (24) hours in which to make a good delivery. But if the seller, after twenty-four (24) hours, fails to make a good delivery, then the buyer shall notify the Superintendent of the Exchange, who shall collect a penalty of three per cent of the amount of the transaction, the Exchange retaining twenty-five per cent of this sum, and seventy-five per cent shall be paid to the buyer.

RULE 21. Spot sales under the Call shall be for spot cash unless otherwise agreed.

RULE 22. All failures in meeting contracts shall be reported to the Superintendent of the Exchange, and announced at next regular session of the Exchange.

CHEESE PROBLEMS (Fisk)

Estimating cheese yield of milk, using fat-content as a basis of calculation.

The results of careful experiments show that within reasonable limits the yield of cheese increases with the percentage of fat in the milk.

Percentage of Fat in the Milk	Pounds of Cheese from 100 Pounds of Milk	Pounds of Cheese for 1 Pound of Fat in Milk
3.0	8.28	2.76
3.5	9.41	2.68
4.0	10.56	2.64
4.8	12.51	2.60

Problem 1

How much more cheese can be made from 2000 lb. of milk testing 4 per cent fat than from 2000 lb. of milk testing 3.5 per cent fat?

2000 × .04 = 80 (lb. of fat)

If each pound of fat in milk testing 4% fat yields 2.64 lb. of cheese, then

80 × 2.64 = 211.2, number of lb. of cheese from 2000 lb. of milk testing 4%

2000 × .035 = 70 (lb. of fat)

If each pound of fat in 3.5% milk yields 2.68 lb. of cheese, then

70 × 2.68 = 187.6, number of lb. of cheese from 2000 lb. of 3.5% milk

211.2 lb. cheese − 187.6 lb. cheese = 23.6 lb. cheese. *Answer.*

Problem 2

A farmer producing 225 lb. of milk daily, testing 3.5 per cent fat, lives an equal distance from two cheese factories. Cheese-maker A is very careless in his methods and the average loss of fat in his whey is .37 per cent; while cheese-maker B takes more pains, and the average loss of fat in his whey is .29 per cent. When cheese is selling at 13 cents a lb., how much more will the farmer receive in 30 days if he delivers his milk to B rather than to A?

225 lb. milk × 30 = 6750 lb. of milk delivered

.37% − .29% = .08% more fat retained in cheese made by B than by A

6750 (lb. of milk) × .85 = 5737.5, approximate weight in lb. of whey

5737.5 × .0008 = 4.59, number of lb. more fat retained in cheese made by B than by A

If each lb. of fat yields 2.68 lb. of cheese,

4.59 × 2.68 = 12.3, number of lb. more cheese made by B than by A

$.13 × 12.3 = $1.60. *Answer.*

PROBLEM 3

Two farmers each deliver daily 385 lb. of milk to the same cheese factory. A's milk tests 3.5 per cent fat and B's tests 4.5 per cent fat. If they are paid for their milk on the basis of the yield of cheese, how much more will B receive than A in one month, cheese selling for 13 cents a pound?

385 lb. milk × 30 = 11,550 lb. milk delivered by each in 30 days

11,550 × .035 = 404.25, number of lb. fat delivered by A

Each lb. of fat in 3.5% milk yields 2.68 lb. of cheese (see table above)

404.25 × 2.68 = 1083.39, number of lb. of cheese from A's milk

$.13 × 1083.39 = $140.84, amount that A should receive for his milk

11,550 × .045 = 519.75, number of lb. fat delivered by B

Each pound of fat in 4.5% milk yields 2.61 lb. of cheese

519.75 × 2.61 = 1356.55, number of lb. of cheese from B's milk

$.13 × 1356.55 = $176.35, amount that B should receive for his milk

$176.35 − $140.84 = $35.51, amount that B should receive more than A for his milk. *Answer.*

Value of fat usually lost in whey.

PROBLEM 4

A cheese factory determines to make whey butter from 10,000 lb. of whey. It tests .32 of 1 per cent fat. With an overrun of 12 per cent, and butter worth 25 cents a pound, compute the value of the whey butter for one day.

10,000 × .0032 = 32, number of lb. of fat

32 × .12 = 3.84, number of lb. overrun

32 lb. + 3.84 lb. = 35.84, number of lb. butter

25 cents × 35.84 = $8.96, value of whey butter for one day. *Answer.*

Calculating the rate of payment on the fat basis in a coöperative cheese factory.

Milk is often bought for cheese-making on a fat basis, and the patrons are paid according to the amount for which the cheese sells. The rate is obtained in the same way as in the case of a butter factory.

PROBLEM 5

In order to illustrate the method of paying for milk on a fat basis at a cheese factory, take the weights of milk and the fat tests given in the following table:

PATRON NUMBER	POUNDS OF MILK	TEST (PERCENTAGE)	POUNDS OF FAT
1	1,500	4.0	60.00
2	1,000	3.9	39.00
3	940	4.2	39.48
4	860	3.8	32.68
5	3,500	5.0	175.00
6	1,400	4.5	63.00
7	780	4.7	36.66
8	600	4.6	27.60
9	970	4.3	41.71
10	775	3.9	30.22
Total			545.35

Find the rate and the amount of money due each patron.

There were delivered 545.35 lb. of fat, and considering a yield of 2.68 lb. of cheese for every pound of fat (a common estimate) there would be 1461.538 lb. of cheese (545.35 × 2.68 = 1461.538). If this cheese sold at 15 cents a lb., it would bring $219.23 ($.15 × 1461.538 = $219.23). A common price charged by cheese-makers for manufacturing is $1.35 per cwt. of cheese. It would therefore cost $19.73 to make the cheese ($1.35 × 14.6153 = $19.73), and this would leave $199.50 to pay the patrons for their fat. Since there would be $199.50 to pay patrons and 545.35 lb. of fat, each lb. of fat would be worth as much as 545.35 is contained in $199.50, which is $.36582. *Answer.*

The amount of money due each patron for his fat is shown in the following table:

Patron Number	Pounds of Fat	Rate	Amount of Payment	
1	60.00	.36582	$21.95	Answer.
2	39.00	.36582	14.27	Answer.
3	39.48	.36582	14.44	Answer.
4	32.68	.36582	11.95	Answer.
5	175.00	.36582	64.02	Answer.
6	63.00	.36582	23.05	Answer.
7	36.66	.36582	13.41	Answer.
8	27.60	.36582	10.09	Answer.
9	41.71	.36582	15.26	Answer.
10	30.22	.36582	11.06	Answer.

CHAPTER X

FANCY CHEESES

In addition to the cheeses of the cheddar type, there is a great variety of cheeses on the markets both in America and in Europe, many of these different varieties being made in this country, others made abroad and imported. The manufacture of foreign varieties is an important feature of our cheese industry. Of these cheeses which were originally made only in Europe, but which are now being made in considerable quantities in this country, are the American Swiss, Limburger, Roquefort, Camembert, and Brie. The varieties which are imported in the largest amounts are Swiss or Emmenthaler, Stilton, Gorgonzola, Roquefort, and Camembert. In addition to these two groups, many other varieties are manufactured in this country and also imported from Europe. Doane and Lawson[1] describe more than one hundred varieties, many of which differ from each other but slightly. In fact, the different types grade into each other so closely that it is difficult to divide them into distinct groups or types. Brief descriptions of some of the more important ones representing the various types will be given.

LIMBURGER CHEESE

This cheese is made from cow's milk either whole or partly or entirely skimmed, the better grades being made from the whole milk. Arnold gives the average composition of Limburger as

[1] U. S. Bul. 146.

follows: water, 35.64 per cent; fat, 29.82 per cent; proteids, 28.53 per cent; total ash, 5.98 per cent. Limburger is characterized by its very strong odor and flavor, the result of the ripening process due to certain types of bacteria, which are grown upon its surface. It is made from strictly fresh milk, a sufficient amount of rennet being used to coagulate it in about forty minutes. The curd is cut in small cubes and dipped into rectangular forms, usually in groups of five, which give a finished cheese about five inches square and two inches thick. The whey is allowed to drain from the curd without the use of pressure, the cheese being turned frequently to aid in the removal of the whey. After the curd has become sufficiently firm to retain its shape, it is removed to the salting table and salt rubbed daily over the surface, which soon becomes thoroughly inoculated with the proper kinds of bacteria which are already on the curing tables. The growth of these bacteria soon develops a slippery coating over the entire surface of the cheese, which are then placed in the curing rooms, where the temperature and moisture are under complete control. The curd breaks down rapidly, taking on a soft, creamy texture, and in about two months this ripening process has penetrated to the center of the cheese, and it is ready for market. Both New York and Wisconsin manufacture large quantities.

EMMENTAL OR DOMESTIC SWISS (Doane and Lawson) [1]

This is a hard rennet cheese made from unskimmed cow's milk, and has a mild, somewhat sweetish flavor. It is characterized by holes or eyes which develop to about the size of a penny in typical cheeses and are situated from 1 to 3 inches apart. Cheese of the same kind made in the United States is known as Domestic Swiss.

Emmental cheese originated in Canton Bern, Valley of

[1] U. S. Bulletin 146.

Emmental, Switzerland. It is a very old variety. Emmental cheese is now manufactured in every civilized country. In the United States there are many factories, located principally in Wisconsin, New York, and Ohio. In Switzerland the greater part of the milk produced is made into this product, and large districts in France and northern Italy are devoted to its manufacture. The best of the product made in Switzerland is exported, about 5,000,000 pounds coming to the United States annually. Practically as good cheese can be manufactured in the United States as in Switzerland, but prejudice, combined with the fact that much of the domestic product is sold as imported, has held the price at a low level.

There is a slight difference in manipulation of the milk in making Emmental cheese in this country as compared with Switzerland. In the latter country the evening's and morning's milk are made up together, while in the United States it is popularly believed that the evening's milk must be made into cheese immediately after milking, as is done with the morning's milk.

In making the cheese in Switzerland the evening's milk is skimmed; the fresh morning's milk is heated to 108 to 110 degrees F. and the cream from the evening's milk is added and well stirred in. The cooled evening's milk with a little saffron is then added and the whole is mixed. The milk is then brought to a temperature of 90 degrees in summer and 95 degrees in winter and sufficient rennet is added to coagulate the milk in thirty to forty minutes. The whole process is carried through in a huge copper kettle holding 300 gallons of milk. The rennet used is the calf's stomach soaked for twenty-four hours in whey. When the milk has thickened to almost the desired point for cutting, which is practically the same as for ordinary American or cheddar cheese, the thin surface layer is scooped off and turned bottom side up. This is supposed to aid in incorporating the layer of cream with the cheese. The curd is then cut very

coarse by means of a so-called harp. The cheese-maker with a wooden scoop in each hand then draws the mass of curd toward him, that lying on the bottom of the kettle being brought to the surface. At this point the cheese-maker and an assistant commence stirring the curd with the harp, a breaker having first been fitted to the inside of the kettle to interrupt the current of the whey and curd. The harps are given a circular motion and cut the curd very fine — about the size of wheat kernels or smaller.

After this stage is reached, heating is commenced. In Switzerland all of the heating until recently was done over an open fire, the kettle being swung on a large crane, and most of the factories have the same method at the present time. In this country the same method was followed in the early days of the industry, but at the present time inclosed fireplaces into which the kettle can be swung and doors closed to retain the heat are largely employed. This takes away much of the discomfort of the operation. In a few instances the kettles are set in cement and an iron car containing the fire is run under it. The more modern factories employ steam, and this appears to be the most satisfactory way. When the heating is begun, the contents of the kettle are brought rapidly to the desired temperature, which may be from 126 to 140 degrees, the higher temperature often being necessary to get the curd sufficiently firm. The stirring in the meanwhile continues for about one hour, with slight interruptions near the end of the process when the curd has become so firm that it will not mat together. The end of the cooking is determined by the firmness of the curd, which is judged by matting a small cake with pressure by the hands and noting the ease with which this cake breaks when held by the edge.

When the curd is sufficiently firm, the contents of the kettle are rotated rapidly and allowed to come to a standstill as the momentum is lost. This brings all the curd into a cone-shaped

pile in the center of the kettle. One edge of a heavy linen cloth resembling burlap is wrapped around a piece of hoop iron, and by this means the cloth is slipped under the pile of curd. The mass of curd is then raised from the whey by means of a rope and pulley and lowered into a cheese hoop on the draining table. These hoops are 4 to 6 inches deep and vary greatly in diameter. The cloth is folded over the cheese, a large follower is put on top, and the press is allowed to come down on the cheese. The press is usually a log swung at one end and operated by a double lever. Pressure is continued for the first time just long enough for the curd mass to retain its shape. The hoop is then removed, the cheese turned over, and a dry cloth substituted. The cheese is allowed to remain in the press about twenty-four hours, during which time it is turned and a dry cloth substituted several times (six or more).

At the end of the pressing the curd should be a homogeneous mass without holes. The cheese is then removed to the salting board, covered with a layer of salt, and turned occasionally. In a day or two it is put in the salting tank in a brine strong enough to float an egg; it remains here at the discretion of the cheese-maker for one to four days. Often no brine tank is used with Emmental cheese.

The cheese is then taken to the curing cellar. In the best factories two or more cellars with different temperatures are available, and the cheeses are placed in them according to the way the cheese-maker thinks their development requires. If it appears that the cheese may develop too fast and have too many and too large eyes, the cheese is placed in a cool cellar; if the reverse is true, a warm cellar is selected. The cellars vary in temperature from 55 to 65 degrees, though in extreme cases 70 degrees or a little higher may be used. While the cheeses are in the ripening cellar, which in Switzerland may be six to ten months or longer, and in the United States three to six months, they should be turned and washed every other day

for the first two or three months and at longer intervals subsequently, and at the same time a little coarse salt is sprinkled on the surface. In a few hours this salt has dissolved, and the brine is spread over the surface with a long-handled brush.

The cheeses are very large, about 6 inches in thickness and sometimes as much as 4 feet in diameter, and weigh from 60 to 220 lb. In shipping, a number of them are placed in a tub which may contain 1000 lb. of cheese. Sometimes Emmental cheese is made up in the form of blocks instead of like millstones. The blocks are about 28 inches long and 8 inches square in the other dimensions.

STILTON CHEESE (Doane and Lawson)

This is a hard rennet cheese, the best of which is made from cow's milk to which a portion of cream has been added. It was first made near the village of Stilton, Huntingdonshire, England, about the middle of the eighteenth century. It is now made principally in Leicestershire and west Rutlandshire, though its manufacture has extended to other parts of England. Its manufacture has been tried, though without success, in the United States. The cheese is about 7 inches in diameter and 9 inches high and weighs 12 to 15 lb. It has a very characteristic wrinkled or ridged skin or rind, which is likely caused by the drying of molds and bacteria on the surface. When cut it shows blue or green portions of mold which give its characteristic piquant flavor. The price in this country is about 45 cents a pound wholesale. The cheese belongs to the same group as the Roquefort of France and the Gorgonzola of Italy.

The morning's milk is put in a tin vat and the cream from the night's milk is added, and the whole is brought to a temperature of 80 degrees F., when the rennet is added. It is claimed by

some cheese-makers that the curd should be softer when broken up or cut than the curd for cheddar cheese, while by others it is believed that it should become very firm before it is disturbed, allowing one to two hours for setting. When sufficiently firm, the curd is dipped into cloths which are placed in tin strainers. After draining for one hour the cloths containing the curd are packed closely together in a large tub and allowed to remain for twelve hours, when they are again tightened and packed for eighteen hours. The curd is ground up coarse and salt is added, 1 lb. to 60 lb. of curd. The curd is then put into tin hoops 8 inches in diameter and 10 inches deep. The cheeses remain in the hoops for six days, when they are bandaged for twelve days, or until they become firm, and are then placed in the curing room at 65 degrees. Ripened Stilton cheese is of late often ground up and put into jars holding 1 to 2½ lb.

GORGONZOLA (Doane and Lawson)

This variety, known also as Stracchino di Gorgonzola, is a rennet Italian cheese made from whole cow's milk. The name is taken from the village of Gorgonzola, near Milan, but very little of this cheese is now made in that immediate locality. The interior of the cheese is mottled or veined with a penicillium much like Roquefort, and for this reason the cheese has been grouped with the Roquefort and Stilton varieties. As seen upon the markets in this country, the surface of the cheese is covered with a thin coat resembling clay, said to be prepared by mixing barite or gypsum, lard or tallow, and coloring matter. The cheeses are cylindrical in shape, being about 12 inches in diameter and 6 inches in height, and as marketed are wrapped in paper and packed with straw in wicker baskets.

The manufacture of Gorgonzola cheese is an important

industry in Lombardy, where formerly it was carried on principally during the months of September and October, but with the establishment of curing cellars in the Alps, especially near Lecco, the manufacture is no longer confined to this season.

The milk used in making this cheese is warmed to a temperature of about 75 degrees F. and coagulated rapidly with rennet, the time required being usually from fifteen to twenty minutes. The curd is then cut very finely and inclosed in a cloth and drained, after which it is put into hoops 12 inches in diameter and 10 inches high. It was formerly the custom to allow the curd from the evening's milk to drain overnight and to mix it with the fresh warm curd from the morning's milk prepared in the same way. The curd from the evening's milk and that from the morning's milk, crumbled very fine, were put into hoops in layers with moldy bread crumbs interspersed between the layers. The cheese is turned frequently for four or five days, the cloths being changed occasionally, and is salted from the outside, the process requiring about two weeks. It is then transferred to the curing rooms, where a low temperature is usually maintained. At an early stage in the process of ripening the cheese is usually punched with an instrument about 6 inches long, tapering from a sharp point to a diameter of about one-eighth inch at the base. About 150 holes are made in each cheese. This favors the development of the penicillium throughout the interior of the cheese. Well-made cheese may be kept for a year or longer. In the region where made much of the cheese is consumed while in a fresh condition.

ROQUEFORT (Doane and Lawson)

This is a hard rennet cheese made from the milk of sheep. There are, however, numerous imitations or varieties closely resembling Roquefort, such as Gex and Septmoncel, made

from cow's milk. One of the most striking characteristics of this cheese is the mottled or marbled appearance of the interior, due to the development of a penicillium, which is the principal ripening agent. The manufacture of Roquefort cheese has been carried on in the southeastern part of France for at least two centuries. The industry is particularly important in the Department of Aveyron, in which is situated the village of Roquefort, from which the cheese derives its name. It is also made in Corsica. Imitations of Roquefort cheese are made in various countries.

The evening's milk is heated to 140 to 150 degrees F., cooled, and kept overnight. After being skimmed it is mixed with the fresh morning's milk. The mixture is then set with rennet at a temperature of about 90 degrees. In from one to two hours after the addition of rennet the curd is cut until the particles are about the size of walnuts. The whey which rises to the surface is dipped off and the curd is put into hoops which are about 8½ inches in diameter and 3½ inches in height. The hoops are filled usually in three layers, a layer of moldy bread crumbs being interspersed between the first and second and second and third layers. The bread used for this purpose is prepared from wheat and barley flour, with the addition of whey and a little vinegar. It is thoroughly baked and kept in a moist place for four to six weeks, during which time it becomes permeated with a growth of the mold referred to. The crust is removed and the interior is crumbled very fine and sifted. The cheese is subjected to pressure, which is gradually increased, for ten to twelve hours. It is turned usually 1 hour after putting into hoops. At the end of about twelve hours it is wrapped in cloth and taken to the first curing room. The cloths are frequently changed during the ten to twelve days the cheese remains in this place.

Formerly the manufacture of the cheese up to this stage was carried on by the shepherds themselves, but in recent years

centralized factories have been established and much of the milk is collected and there made into cheese. The cheese is then taken to the caves. These are for the most part natural caverns which exist in large numbers in the region of Roquefort. The temperature in these caves is 40 to 45 degrees, and the air circulates very freely through them. Recently artificial caves have been constructed and used. When the cheeses reach the caves they are salted, which serves to check the growth of the mold on the surface. One or two days later they are rubbed vigorously with cloth and are afterwards subjected to thorough scraping with knives, a process formerly done by hand but now much more satisfactorily and economically by machinery. The salting, scraping, or brushing seems to check the development of mold on the surface. In order to favor the growth of mold in the interior, the cheese is pierced by machinery with 60 to 100 small steel needles, which process permits the free access of air. The cheese may be sold after thirty to forty days or may remain in the caves as long as five months, depending upon the degree of ripening desired. The cheese loses during ripening by scraping and evaporation as much as 25 per cent of the original weight. The weight when ripened is about 4½ to 5 lb.

THE MANUFACTURE OF EDAM CHEESE [1]

Edam cheese is a sweet-curd cheese, made from partially skimmed milk. It comes to the market in the form of round, red balls, each weighing from 3½ to 4 lb. when cured. They are largely manufactured in northern Holland and derive their name from a town which is famous as a market for this kind of cheese.

Kind of milk used.

Milk from which one-fourth to one-third of the fat has been removed is used. Too great pains cannot be taken in regard

[1] N. Y. Exp. Sta. Bul. 56.

to the condition of the milk. It should be fresh, free from every trace of taint; in brief, it should be in as perfect condition as it is possible to have milk.

Treatment of milk before adding rennet.

The temperature of the milk should be brought up to a point not below 85° F. nor much above 88° F. When the desired temperature has become constant, then the coloring matter should be added. We used Carter's cheese color, using at the rate of 1½ to 2 oz. for 1000 lb. of milk. The coloring matter should, of course, be added to the milk and thoroughly incorporated by stirring before the rennet is added.

Addition of rennet to milk.

The rennet should not be added until the milk has reached the desired temperature (85° to 88° F.) and this temperature has become constant. When the temperature reaches the desired point and remains there stationary, the rennet extract is added. In our work, Hansen's rennet-extract was used, 4½ to 5½ oz. being taken for 1000 lb. of milk, or enough to coagulate the milk in the desired time, at the actual temperature used. The milk should be completely coagulated, ready for cutting, in about 12 to 18 minutes from the time the rennet was added. The same precaution observed in making cheddar cheese should be followed in making Edam cheese with reference to care in adding the rennet, such as careful, accurate measurement, dilution with pure water before addition to milk, and the like.

Cutting the curd.

When the curd breaks clean across the finger, it should be cut; the curd is cut a very little softer than in the cheddar process as ordinarily practiced. As stated above, this stage of hardness in the curd which fits it for cutting should come in twelve to eighteen minutes after the rennet is added. First, a vertical knife is used and the curd is cut lengthwise, after which it is allowed to stand until the slices of curd begin to show the separation of

whey. Then the vertical knife is used in cutting crosswise, after which the horizontal knife is at once used. Any curd adhering to the bottom and sides of the vat is carefully removed by the hand, after which the curd knife is again passed through the mass of curd lengthwise and crosswise, continuing the cutting until the curd has been cut as uniformly as possible into very small pieces.

Treatment of curd after cutting.

When the cutting is completed, then one commences at once to heat the curd up to the temperature of 93° to 96° F. The heating is done as quickly as possible. While the heating is in progress, the curd is kept constantly agitated to prevent settling and consequent over-heating. As soon as the curd shows signs of hardening, which the experience of the worker will enable him to determine, the whey is drawn off until the upper surface of the curd appears, when one should commence to fill the press-molds.

Filling molds, pressing and dressing cheese.

The molds, which are described later in detail, are well soaked in warm water previous to use, in order to prevent too sudden chilling of curd and consequent checking of separation of whey. As soon as whey is drawn off, as indicated above, one commences to fill the pressing molds (see Fig. 60). The filling should be done as rapidly as possible to prevent too great cooling of curd. When the curd has been put into the molds, its temperature should not be below 88° F. Unless care is taken to keep the curd covered, the portion that is last put into the molds may become too much cooled. In making Edam cheese on a small scale, it is a good plan to squeeze the moisture out by the hands as much as possible and then break it up again before putting in the molds, when the curd should be pressed into the mold by the hands as firmly as possible. The molds

FIG. 60.—Mold for making Edam cheese.

should be filled as nearly alike as possible. The cheese should weigh from 5 to $5\frac{1}{4}$ lb. each when ready for the press. When the filling of molds is completed, they are put under continual pressure of 20 to 25 lb. for about twenty-five or thirty minutes. While the cheese is being pressed, some sweet whey is heated to a temperature of 125° or 130° F., and this whey should not be allowed to go below 120° F. at any time while it is being used. When the cheeses are taken from their molds, each is put into the warm whey for two minutes, then removed and dressed. For dressing Edam cheese the ordinary cheese bandage cloth is used. This is cut into strips, which should be long enough to reach entirely around the cheese and overlap an inch or so, and which should be wide enough to cover all but a small portion of the ends of the cheese when put in place. Before putting on the bandage, all rough projections should be carefully pared from the cheese. In putting on the bandage, the cheese is held in one hand and the bandage is wrapped carefully around the cheese, so that the whole cheese is covered, except a small portion on the upper and lower surface of the cheese. These bare spots are covered by small pieces of bandage cloth of a size sufficient to cover the bare surface. The bandage is kept wet with the warm sweet whey, thus facilitating the process of dressing. After each cheese is dressed, it should be replaced in the pressing mold, care being taken that the bandage remains in place and leaves no portion of the surface of the cheese uncovered and in direct contact with the mold. The cheese is then put under continual pressure of 60 to 120 lb. and kept under this continual pressure for six to twelve hours.

Salting and curing.

There are two methods which may be employed in salting, — dry-salting and wet-salting. In dry-salting, when the cheese is finally taken from the press, it is removed from the press mold, its bandage is removed completely, and the cheese placed in another mold, quite similar, known as the salting mold. Each

cheese is placed in a salting mold with a coating of fine salt completely surrounding it. The cheese is salted in this way once each day for 5 or 6 days. Each day the cheese should be turned when it is replaced in the mold, so that it will not be rounded on one end more than the other. This is for the purpose of making both ends uniform in shape, giving each the proper rounding peculiar to the shape of the cheese. In the method of wet-salting, the cheese is placed in a tank of salt brine, made by dissolving common salt in water in the proportion of about one pound of salt to $2\frac{1}{2}$ quarts of water. Each cheese is turned once a day and should be left in the brine 7 or 8 days. When the cheese is taken from the salting mold or salt bath it is placed in warm water and is given a vigorous, thorough brushing in order to remove all slimy or greasy substances that may have accumulated on the outer surface of the cheese. When the surface of the cheese is well cleansed, it is carefully wiped dry with a linen towel and placed upon a shelf in the curing room. In being placed on the shelves, the cheese should be placed in contact so as to support one another, until they have flattened out at both ends so much that they can stand upright alone. Then they are placed far enough apart to allow a little air space between them. Another method of securing the flattened ends is to support each cheese on opposite sides by wedge-shaped pieces of wood. After they are placed on the shelves in the curing room, they are turned once a day and rubbed with the bare hand during the first month, twice a week during the second month, and once a week after that. When any slimy substance appears on the surface of the cheese, it should be washed off at once with warm water or sweet whey. The special conditions of the curing room will be noticed in detail below. When the cheeses are about two months old, they can be prepared for market, which is done in the following manner: They are first made smooth on the surface by being turned in a lathe or in some other manner, after which the surface is colored. For coloring, some carmine

is dissolved in alcohol or ammonia to get the proper shade, and in this color-bath the cheeses are placed for about one minute, when they are removed and allowed to drain, and as soon as they are dry the outside of each cheese is rubbed with boiled linseed oil, in order to prevent checking. They are then wrapped in tin-foil, which is done very much like the bandaging. Care must be taken to put the tin-foil on so that it presents a smooth, neat appearance. The cheeses are finally packed in boxes, containing 12 cheeses in each box, arranged in two layers of six each with a separate partition for each cheese.

Curing room.

Much more attention must be given to the conditions of the curing room as regards moisture and temperature than in the case of cheddar cheese. The curing room should be well ventilated, should be quite moist, and its temperature should be kept between 50° and 65° F. These are conditions which are not easy to secure in any ordinary room. Some form of cellar is best adapted to secure these conditions. The amount of moisture can be determined by an instrument known as a hygrometer, which consists of two thermometers; the bulb of one is exposed to the air directly and is known as the dry-bulb thermometer; the bulb of the other is wrapped with a piece of cloth, preferably flannel, the lower end of which is placed in water, and this is known as the wet-bulb thermometer. The dry-bulb thermometer indicates the temperature of the air in the room; the wet-bulb thermometer indicates a lower temperature because the water evaporates from the bulb and the evaporation is accompanied by a lowering of temperature immediately around the wet-bulb. The less moisture there is in the air, the more rapidly will evaporation take place and the lower will be the temperature indicated by the wet-bulb thermometer. The greater the moisture, the less will be the amount of evaporation, and the smaller the difference between the wet- and dry-bulb thermometers. When the two thermometers indicate the same tem-

perature, then there is no evaporation taking place at the wet-bulb thermometer, because the air is saturated with moisture or holds all that it can at that particular temperature. In a curing room suited for Edam cheese, the moisture should be between 85 and 95 per cent, or a little short of saturation. When the temperature is between 50° and 65° F., the moisture is between 85 and 95 per cent if the wet-bulb thermometer is from one to two degrees F. (or $\frac{1}{2}$° to 1° C.) below the dry-bulb thermometer. Undoubtedly, much better results would be secured in curing cheddar cheese, if some attention were paid to the condition of moisture of the air in the curing room, for it is now extremely rare to find any cheese-maker recognizing this condition at all. In the case of Edams, the cheese will check or crack and be spoiled for market, if the degree of moisture is not kept high enough.

Utensils employed in making Edam cheese.

Aside from the molds, continual press and salting vat, the same apparatus that is used in making cheddar cheese can be used in making Edam cheese. The pressing mold is turned preferably from white wood or, in any case, from wood that will not taint. Each mold consists of two parts; the lower part constitutes the main part of the mold, the upper portion is simply a cover. The lower portion or body of the mold has several holes in the bottom, from which the whey flows when the cheese is pressed. Care must be taken to prevent these holes being stopped up by curd. This portion of the mold is about six inches deep and six inches in diameter across the top. The salting mold has no cover and the bottom is provided with only one hole for the out-flow of whey; in other respects it is much like the pressing mold.

Qualities of Edam cheese.

The flavor of a perfect Edam cheese is difficult to describe. It is mild, clean, and pleasantly saline. In imperfect Edams the flavor is more or less sour and offensive.

In body, a perfect Edam cheese is solid, rather dry and mealy or crumbly. This condition is secured by the use of partially skimmed milk together with the special conditions of manufacture employed.

In texture, the perfect Edam cheese should be close and free from pores.

Loss of milk-solids in manufacture of Edam cheese.

The amount of milk-solids in 100 lb. of the milk (partially skimmed) varied from 11.20 to 12.21 lb. and averaged 11.61. Of this amount, from 6.02 to 6.34 lb. were lost in the whey, with an average of 6.21 lb.; which was equivalent to 51.43 to 55.65 per cent of the milk solids, with an average of 53.50 per cent. These results confirm the results of our previous study of skimmed milk in respect to loss of milk-solids in cheese-making, though the losses here are greater than would ever occur in making the same milk into cheddar cheese.

Amount of fat lost and recovered in the manufacture of Edam cheese.

The amount of fat in 100 lb. of the partially skimmed milk varied from 2.45 to 3.20 lb. and averaged 2.77 lb. Of this amount, from 0.30 to 0.51 lb. of fat were lost in the whey, with an average of 0.39 lb.; which was equivalent to 11.18 to 18.89 per cent of fat in the milk, with an average of about 14 per cent. These results show a considerably larger loss of fat in the process of making Edam cheese than in the ordinary process of making cheddar cheese.

Influence of composition of milk on yield of cheese.

TABLE SHOWING RELATION OF MILK CONSTITUENTS TO YIELD OF CHEESE

No. of Experiment	Pounds of Fat in 100 Lb. of Milk	Pounds of Casein and Albumin in 100 Lb. of Milk	Pounds of Green Cheese Made from 100 Lb. of Milk	Pounds of Water in Cheese Made from 100 Lb. of Milk	Pounds of Fat in Cheese Made from 100 Lb. of Milk	Pounds of Casein and Albumin in Cheese Made from 100 Lb. of Milk
164	2.45	3.13	9.60	4.58	2.06	2.37
155	2.50	3.20	11.15	6.17	2.20	2.50
165	2.55	3.10	9.85	4.50	2.23	2.36
158	2.60	3.05	10.25	4.78	2.17	2.33
153	2.65	3.13	10.10	4.84	2.35	2.40
157	2.65	2.91	10.37	4.98	2.26	2.19
163	2.65	3.13	10.26	4.86	2.22	2.36
159	2.70	2.83	10.80	5.79	2.19	2.14
154	2.75	3.11	11.24	6.02	2.42	2.38
161	2.90	3.21	10.55	5.11	2.49	2.45
156	2.95	2.95	11.82	6.15	2.62	2.24
162	3.10	3.17	10.63	5.02	2.66	2.40
152	3.15	3.31	10.30	4.50	2.73	2.48
160	3.20	3.26	10.90	4.97	2.76	2.49

Yield of green cheese from one hundred pounds of milk.

The yield of cheese from 100 lb. of milk varied from 9.60 to 11.82 lb. and averaged 10.56 lb.

Amount of water retained in cheese.

In the cheese made from 100 lb. of milk there were retained from 4.50 to 6.17 lb. of water with an average of 5.16 lb. This is a very much larger amount of water than is retained in cheese made from normal milk by the ordinary cheddar process. Edam cheese loses about 8 per cent of its weight in curing.

Comparison of Edam and American cheddar cheese with reference to profit in manufacture.

In comparing the profit derived from the manufacture of Edam and American cheddar cheese, we must consider the

character of the milk used in making Edam cheese, — it is approximately one-fourth or one-third skimmed milk. American cheddar cheese made from milk of this character would hardly wholesale, on an average, for over 7 cents a pound or, say, about 70 cents for the cheese made from 100 lb. of milk. On the other hand, Edam cheese made from the same milk would wholesale for from 15 to 20 cents a pound, which, for 100 lb. of milk, would equal from $1.50 to $2.00. After calculating the increased cost involved in making Edam cheese, it is a conservative estimate to say that the money received for 100 lb. of milk will be about double the amount received for the same milk when made into cheddar cheese.

THE MANUFACTURE OF GOUDA CHEESE [1]

Gouda cheese is a sweet-curd cheese made from whole milk. In shape, the Gouda cheese is somewhat like a cheddar with the sharp edges rounded off and sloping toward the outer circumference at the middle from the end faces. They usually weigh 10 or 12 lb., though they vary in weight from 8 to 16 lb. They are largely manufactured in southern Holland, and derive their name from the town of the same name.

Fresh, sweet milk that has been produced and cared for in the best possible manner should be used.

Treatment of milk before adding rennet.

The temperature of the milk should be brought up to a point not below 88° F. nor much above 90° F. When the desired temperature has been reached and has become constant, then the coloring matter is added. We used one ounce of Hansen's cheese color for about 1200 lb. of milk. The coloring matter should be thoroughly incorporated by stirring before the rennet is added.

Addition of rennet to milk.

The rennet should not be added until the milk has reached the desired temperature (88°–90° F.) and this temperature has be-

[1] N. Y. Exp. Sta. Bul. 56.

come constant. The milk should be completely coagulated, ready for cutting, in fifteen or twenty minutes. The same precautions should be used in adding rennet as those previously mentioned in connection with the manufacture of Edam cheese.

Cutting the curd.

The curd should be cut when it is of about the hardness generally observed for cutting in the cheddar process. The cutting is done exactly as in the cheddar process except that the curd is cut a little finer in the Gouda cheese. Curd should be about the size of peas or wheat kernels when ready for press and as uniform in size as possible.

Treatment of curd after cutting.

When the cutting is completed, one commences at once to heat the curd and to stir carefully. The heating and constant stirring are continued until the curd reaches a temperature of 104° F., which should require from thirty to forty minutes. When the curd becomes rubber-like in feeling and makes a squeaking sound when chewed, the whey should be run off. The whey should be entirely sweet when it is removed.

Pressing and dressing cheese. (See Fig. 61.)

After the whey is run off, the curd is put in the molds at once without salting. Pains should be taken in this process to keep the temperature of the curd as near 100° F. as possible. Each cheese is placed under continual pressure amounting to 10 or 20 times its own weight and kept for about half an hour. The first bandage is put on in very much the same manner as the bandage in Edam cheese-making. The cheese is then put in press again for about one hour. The first bandage is then taken off and a second one like the first put on with great care, taking pains to make the bandage smooth, capping the ends as before. The cheese is then put in press again and left twelve hours or more.

Fig. 61. — Mold for Gouda cheese.

Salting and curing.

When the cheese is taken from the press the bandage is removed and it is placed for twenty-four hours in a curing room like that used in curing Edam cheese, as previously described (p. 364). Each cheese is then rubbed all over with dry salt until the salt begins to dissolve, and this same treatment is continued twice a day for ten days. At the end of that time, each cheese is carefully and thoroughly washed in warm water and dried with a clean linen towel. The cheeses are then placed on the shelves of the curing room, turned once a day and rubbed like cheddars. The temperature and moisture are controlled as described in curing process of Edam cheese. If the outer surface of the cheese gets slimy at any time, they are carefully washed in warm water and dried with clean towels. Under these conditions, the cheese ripens in 2 or 3 months.

Utensils employed in making Gouda cheese.

The molds, continual press, and curing room are the only things needed in the making of Gouda cheese that differ from the utensils employed in making cheddar cheese. The mold used for Gouda cheese consists of two portions, which are shown separate in Fig. 61. These molds were made of heavy pressed tin. The inside diameter at the middle is about 10 inches. The diameter of the ends is about 6½ inches. The height of the mold (as seen in Fig. 61) is about 5½ inches, and this represents the thickness of the cheese, but by pushing the upper down into the lower portion, the thickness can be decreased as desired.

Loss of fat in the manufacture of Gouda cheese.

The amount of fat in 100 lb. of milk varied from 3.75 to 4.50 lb. and averaged 4.21 lb. Of this amount of fat, there were lost in the whey from 0.29 to 0.43 lb. with an average of 0.35 lb. This was equivalent to from 7.73 to 9.66 per cent of the fat in the milk, with an average of 8.30 per cent. The loss of fat

appears to be not much greater than the average loss met with in cheese factories in making cheddar cheese. A little larger loss would be expected from the higher temperature used in heating the curd.

Loss of casein and albumen in the manufacture of Gouda cheese.

The amount of casein and albumen in 100 lb. of milk varied from 3.17 to 3.68 lb. and averaged 3.48 lb. Of this amount, there were lost in the whey from 0.71 to 0.90 lb., with an average of 0.83 lb. This was equivalent to 22.40 to 24.45 per cent of the casein and albumen in the milk, with an average of 23.70 per cent.

Yield in the manufacture of Gouda cheese.

From 100 lb. of milk, there were made from 11.60 to 13.35 lb. of green cheese, with an average of 12.50 lb. This was equivalent to nearly 3 lb. of green cheese for 1 lb. of fat in milk. This large yield is due to retention of moisture, which varied from 4.95 to 5.79 lb. and averaged 5.40 lb. for the cheese made from 100 lb. of milk. The amount of water in 100 lb. of cheese varied from 41.25 to 45.43 lb. and averaged 43.50 lb. In two months, the cheese had lost about 17.5 per cent of their weight in curing.

DIRECTIONS FOR MAKING THE CAMEMBERT TYPE OF CHEESE
(B. A. I. Bulletin No. 98)

The cheese-making plant

The first problem to be considered is the construction of a suitable plant in which the cheese is to be made and ripened. The description which is here given is not of the plant in which our experiments have been carried out, but is rather of one which is designed to meet certain requirements discussed later, and which experience has taught us would be most satisfactory.

The plant suggested consists of three rooms, the first of which

is used for the making of the cheese, the second for growing the molds and for the first stage of ripening, and the third for the subsequent and final ripening. The size of these rooms depends chiefly upon the quantity of milk which is to be handled.

Equipment of the making room.

Vats. — For the making of Camembert cheese an ordinary flat-bottomed cheese vat is just as satisfactory as the basins used in France.

FIG. 62. — Curd knife and dipper.

Apparatus for determining ripeness. — A Marschall rennet test is useful in testing the ripeness of the milk. A more convenient and accurate apparatus, however, is one for determining the percentage of acidity, and consists of a burette connected by a siphon to a large bottle of a one-tenth normal solution of caustic soda ($N/10$ NaOH).

Curd knife and dipper. — A curd knife of the ordinary type must be provided in case the curd is to be cut, and also a dipper similar in shape to a soup ladle (see Fig. 62).

Draining table. — The draining table, one end of which is a little higher than the other, is placed near the vat. The top of this table slopes somewhat from both sides toward the center. It is best to have the table on wheels, so that it will be movable.

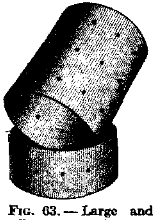


FIG. 63. — Large and small forms for Camembert cheese.

Hoops, or forms (see Fig. 63). — The hoops in which the cheeses are made are cylindrical in shape and open at both ends. They are made of galvanized iron, are 5 inches in height and 4 inches in diameter, and are provided with three rows of holes about 1 inch apart. The size of the holes is about one-eighth of

an inch, and there are thirteen holes in a row. A second set of hoops, 2 inches in height, with one row of holes around the center, is made with a slightly larger diameter (one-eighth of an inch larger is sufficient), so that they will slide freely over the others.

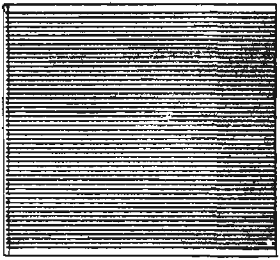


FIG. 64. — Draining board for Camembert cheese.

Boards (see Fig. 64). — The draining boards are made of whitewood and have parallel grooves on both sides to enable the whey to run off readily. These grooves are about one-sixteenth of an inch wide and of the same depth, and are about one-eighth of an inch apart. The boards are about 14 by 15 inches in size, or large enough to hold nine cheeses of common size.

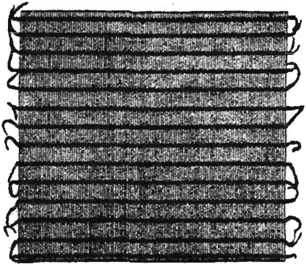


FIG. 65. — Draining mat.

Mats (see Fig. 65). — Square mats of the same size are needed to cover these boards. They are preferably made of fine bamboo strips, closely fastened together with strings. They resemble somewhat the bamboo strip curtains.

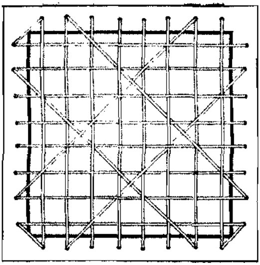


FIG. 66. — Cane support for ripening cheese.

Cane bottoms (see Fig. 66). — Cane bottoms are often used. They are of the same size as the draining boards and are used as supports for the cheese during the ripening process.

Equipment of ripening rooms. The equipment necessary for the ripening rooms consists of shelves on which the cheeses rest and means for controlling at all times the temperature and moisture of the rooms. The shelves are made of hardwood and are about 5 inches apart, so as to allow the boards and cheeses to slide in and out freely. They are built from floor to ceiling in order to economize space. Steam and brine pipes will best furnish the means of controlling temperature and moisture.

Construction and condition of the rooms

Making room. — One of the first requirements is that of absolute cleanliness. The floor should be of cement or some other water-tight material, and should slope toward a drainpipe, so that it can be readily flushed with water. The walls can be made of wood or brick, preferably the latter, and should be covered with whitewash or enamel paint. This coat of whitewash or paint should be renewed from time to time after cleaning off any dirt that may accumulate, and also for the purpose of disinfecting the room if this should be needed. The room must be frequently ventilated, no matter what the temperature of the outside air may be, and yet it is to be maintained

at a constant temperature. For this purpose steam should be provided, as stoves or other heating arrangements do not warm the room as quickly or satisfactorily. An ordinary dairy sink, with water and steam taps, is necessary. The steam pipe should connect with the water pipe by a tee, so that the water can be heated to any desired temperature. As the tools cannot be properly cleaned with hot water alone, it is advisable to provide a steam chest or sterilizer of some sort where they can be left in contact with live steam. A strong wooden box, lined with galvanized iron and having a valve at the bottom as an outlet for condensed water, has been found to be very satisfactory. It is provided with a strong cover, which can be fastened to the box with clamps. The whole arrangement should be made so as to stand a slight pressure. This box is especially useful for sterilizing the boards and cane bottoms used to hold the cheeses during the ripening process.

First ripening room. — The first ripening room must be nearly saturated with moisture and kept at a temperature of about 60° to 62° F., as these conditions are most suitable for the proper growth of mold.

Second ripening room. — This room is to be kept somewhat cooler (56° to 60° F.), as the ripening proceeds more uniformly at this temperature. Here it is not necessary to keep such a high percentage of moisture as in the first room. There should be just enough to keep the cheeses from drying out. The walls and floors of both of these rooms should be like those of the making room — that is, easy to clean. Both of the ripening rooms should be well ventilated and steam heated. The steam can be used not only for heating, but also for maintaining the desired degree of moisture. In summer the outside heat would raise the temperature of the rooms, causing the cheese to ripen too fast and not uniformly. For that reason some means of cooling must be provided.

Protection against insects.

A very important item is that of protecting the cheese against flies and other injurious insects. The outer doorways, the windows, and every other possible opening should be carefully guarded by screens with as fine a mesh as can be procured, as the smallest flies produce the most trouble. If this is not carefully attended to, the cheeses are sure to become infested with fly maggots. In the ripening rooms protection against these insects can be secured to a considerable extent by keeping the rooms dark, for flies will not readily breed and multiply in a dark place.

The making of the cheese

The milk.

The milk used in making Camembert cheese should be of the best quality — that is, clean and fresh. Two quarts of milk are required for each cheese.

Ripening the milk.

The milk is poured into the vat and by the aid of water and steam is heated to 85° F., this being the temperature best suited for the growth of the lactic bacteria. A starter is added, the amount depending on its strength and capacity for developing lactic acid, usually 3 quarts of a medium starter for every 100 lb. of milk. After adding the starter the milk is allowed to stand until the desired degree of acidity is reached.

This method of ripening the milk before setting is not the rule in France, where they generally set the milk at a very low degree of acidity without any attempt at previous ripening of the milk. The acid, however, develops later in the curd while the cheese is draining. In our experience serious trouble from gas has been avoided by ripening the milk before setting. Especially during the hot weather it is advisable to use a higher degree of acidity. The percentage of acidity used by us is rather high (about 0.35 per cent). This is, however, partly because of the low temperature of the room in which our experi-

ments are made. In France the making rooms are generally kept quite warm, and the cheese will naturally drain faster there and develop the acid in the curd.

Several experiments have shown us that it is not entirely necessary to use such a high degree of acidity to secure a properly drained cheese, but by using a starter which will work rapidly after the cheese is dipped, very satisfactory results have been obtained. The milk in such cases was ripened only to about 0.2 to 0.25 per cent of acid.

The starter.

It is best to use a starter which is a pure culture of lactic organisms, prepared by inoculating sterilized milk with these bacteria. In cheese- and butter-making some home-made starter is generally used, such as sour milk or buttermilk. These often give excellent results, but are by no means pure cultures and cannot be depended upon; in fact, they sometimes cause considerable trouble.

The various commercial starters have been used here and have produced excellent cheese of a mild type. The one found most satisfactory, however, was prepared from a certain brand of imported cheese. This cheese has a peculiar flavor of its own, which differs from that of any other brand. Experiments to produce this flavor have been carried out here. After many of these imported cheeses had been carefully examined and analyzed a certain kind of lactic acid organism was found by the bacteriologist. This organism was separated, and from it a pure-culture starter prepared, which was used in the making of the cheese with excellent results. The flavor sought for has been produced repeatedly with this starter. As this brand of cheese is more popular than almost any other, this starter is probably the best that can be used in the manufacture of this cheese.[1]

[1] As soon as a demand for this starter arises in the trade, cultures of it will be furnished to such companies as regularly supply starters for other creamery work.

Adding the rennet.

The milk while ripening cools down unless carefully watched. If this has occurred, it must be brought back to the original temperature (85° F.) before adding the rennet. At this temperature it has been found necessary to use a curdling time of one and one-half to two hours to secure the texture of the curd desired for Camembert cheese. The amount of rennet required to curdle the milk in this time is calculated by means of the Marschall rennet test or the titration apparatus.

Cutting the curd.

In France the method in general use consists in dipping the curd directly into the forms. Equally good results in most respects, however, have been obtained here with the curd cut. In cutting, the curd knife is passed through the curd in the vat in two directions at right angles, thus producing vertical columns of curd. When the curd has been cut in this way it drains faster, and for that reason a lower degree of acidity is used than with the curd uncut.

The most satisfactory acidity with cut curd has been found to be from 0.3 to 0.35 per cent. If it is less, the curd is likely to be too soft; if higher, the curd will drain too rapidly, will become hard and compact, and will not ripen properly. The acidity is tested as follows: a sample of milk is taken with a Babcock pipette holding 17.6 c.c. and is transferred to a glass or beaker. A few drops of phenolphthalein are added and $N/10$ NaOH is run in from the burette, drop by drop, until a pink color just begins to appear. The number of cubic centimeters of soda solution used, divided by 20, gives the percentage of acid in the milk.

The higher the acidity of the milk, the less rennet it takes. In case the acidity is 0.3 per cent, it will take about 8 to 10 c.c. of the ordinary rennet extract to every 100 lb. of milk to bring the curd to the right consistency in one and one-half to two hours. The necessary amount of rennet is poured into a glass of water

and then mixed thoroughly with the milk. The milk is now left to stand until it has coagulated to the proper consistency. It is impossible to describe any test which will show when the curd is firm enough. This can only be ascertained by practical demonstration; after a little practice the maker can generally tell just when the curd is ready to cut. The curd of Camembert cheese is much firmer than that of cheddar or Swiss cheese.

After the curd has been cut it is stirred gently once or twice with the dipper to separate the columns and hasten the separation of the whey. Then it is allowed to stand for about fifteen minutes to make it a little firmer. The whey separates out at the surface, and the bulk of it is dipped off.

If, however, the curd is quite firm, less of the loose whey is dipped off. The contents of the vat are now stirred to insure uniformity, otherwise part of the cheese would be softer than the rest.

Dipping the curd into the forms (see Fig. 67).

The next operation is the dipping. This is done with a ladle which just fits into the forms. Place the draining table near the vat, and upon it arrange the boards, each covered with a mat and holding nine of the high forms. Into each of these forms a dipperful of curd is placed, care being taken to bring the dipper inside the forms in order to prevent splashing and breaking the curd. After one dipperful is placed in each form the operation is repeated, the dipping continuing until the forms are all filled to the top.

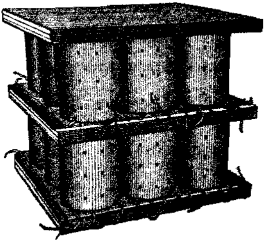


FIG. 67. — Forms, mats and boards, arranged for draining the cheese.

After the curd has all been dipped into the hoops the latter are piled up, together with the boards, one upon the other. This is done partly to save space and partly to cover up the cheese and thus keep off any dirt or flies which otherwise might fall upon them. The top of the pile is then covered with an extra board.

The curd is now allowed to drain without any artificial pressure for four or five hours. At the end of this time it will have shrunk to about half the original volume and will be ready for inoculation of molds and turning.

Inoculation and turning (see Fig. 68).

Although it is not customary for French cheese-makers to inoculate Camembert cheese with mold, we have found it very desirable. Under the conditions found in Normandy the cheese acquires its moldy covering rapidly enough by accidental inoculation. Even then undesirable molds often appear to the injury of the cheese. In our experimental work artificial inoculation on the day of making has been necessary to secure satisfactory results.

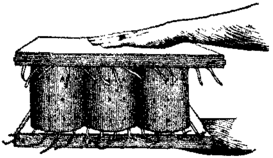


FIG. 68. — Method of turning the cheese.

Where dependence is placed on accidental inoculation, undesirable molds often get on the cheeses ahead of the Camembert mold, the result being either a poor cheese or one spoiled entirely. On the other hand, if a cheese is inoculated with the Camembert mold at the outset, this will grow and cover the cheese rapidly, which practically protects the cheese from the infection of other molds. A very good proof of this statement is that one can almost always find some other species of molds on imported cheese, while the molds found on inoculated cheeses are gener-

ally pure cultures, unless the culture with which they were inoculated was of poor quality. It is necessary that the maker should know the right mold when he sees it.

A most satisfactory way of inoculating is as follows: Take a small jar with a tin cover which has been punched full of small holes, like an ordinary pepper box, fill it half full with water, add a piece of moldy cracker or a piece of cheese with a good growth of the proper mold, and shake thoroughly. The contents of the jar are now sprinkled upon the surface of each cheese, then the cheeses are turned and inoculated in the same manner on the other side.

Another simple and very convenient way of inoculation, especially adapted to use in large factories, consists in taking two cheeses well covered with mold and knocking them together over the hoops. In this way enough spores drop upon the cheese to give good results.

This inoculation is by the *Penicillium camemberti;* but a second mold, *Oidium lactis,* seems to be necessary for the production of flavor in Camembert cheese, as has been indicated in a previous paper.[1] The latter is mostly found in milk and will appear on the cheese slowly. To insure its rapid growth the cheese may be inoculated with it also. The same method of inoculation may be employed as with the other mold, except that *Oidium lactis* is grown in a gelatin culture medium instead of upon crackers.

The cheeses are turned, not only to secure the inoculation of both sides, but also to prevent them from becoming too compact on the underside on account of the greater pressure there and to insure a smoother surface on both sides. The quickest and easiest way to turn the cheeses is to cover the nine forms with a second mat and board. Place one hand under the lower board and the other over the upper, and then invert (Fig. 68). If

[1] Bulletin No. 82, Bureau of Animal Industry.

the cheeses thus turned do not rest flat on the bottom, they are straightened out by moving the forms.

After turning and inoculating, the cheeses are left without any further handling until the next morning, when they are taken out of the forms and salted. By this time they have shrunk almost to their final size. In case they are not yet hard enough to be safely handled, they are turned again and left to stand until they are sufficiently firm.

Salting (see Fig. 69).

The salting is done by taking two cheeses together and rolling the edges and rubbing their surfaces in salt (Fig. 69). The salt to be used should not be too fine, as this would produce over-salting.

Fig. 69. — Salting the cheese.

After salting, the cheeses are placed upon dry boards, so that the sides which were previously at the top will now be at the bottom. The next morning it will be found that all of the salt has dissolved, and that most of it is diffused in the cheese. The cheeses are again transferred to another dry board or cane bottom, after turning, and are ready for the ripening process. The reason for transferring them to dry boards is that a dry board is less apt to become covered with mold.

Making cheese from uncut curd.

A cheese from uncut curd is made somewhat differently. Although the cut curd drains more rapidly, the draining of the uncut curd can be greatly facilitated by allowing the milk to become more acid before adding the rennet.

In our experiments the degree of acidity giving the most satisfaction in the uncut curd has been about 0.40 per cent. The amount of rennet to be added varies inversely as the acidity. When the curd has reached the proper consistency, it is dipped into the hoops in the same way as the cut curd, but the operation

should be carried out more slowly. After the forms have been filled the cheeses are allowed to stand without turning until the next morning. This is because the successive dipperfuls of uncut curd do not stick together readily at first and must be given more time.

While turning the cheese the next morning they are to be inoculated. They must then be left until the following morning, by which time they are ready to be salted. After salting they remain another day in the making room, making three days all together, instead of two as in the case of the cut-curd cheese.

In France the cheeses are always made of uncut curd, but no reason has ever been given for the practice, so far as the writer knows. In a series of experiments where cheeses were made of the same milk with cut as well as uncut curd for comparison, we found that in almost every case the uncut-curd cheese, even when fully ripe, did not decompose as quickly as the cut-curd cheese. Other advantages are that more cheese is produced from the uncut curd from the same amount of milk, and the loss of fat in the whey is not so great.

The use of the low forms.

Both cut and uncut curd cheeses should be hard enough to bear handling at the time of salting, but often they are not yet hard enough to retain their shape. In such cases they should be put at the time of salting into the low forms, where they remain until the next morning. When they can hold their shape without the aid of the forms, they are taken to the ripening room.

Ripening the cheese

The cheeses are removed to the first ripening room. Here they are placed on smooth boards upon shelves. The boards are of the same size as the draining boards, but have a smooth surface. The cheeses remain on these boards during the whole ripening period. Cane bottoms are frequently used and are

preferable to the boards for the following reasons: When boards are used, the molds are apt to grow iuto the wood, causing the latter to stick so tenaciously that on turning the cheeses over the rind is torn off. On the other hand, when cane bottoms are used the mold can grow more uniformly on both sides of the cheeses, and as they do not stick to the bottoms so tenaciously, it is necessary to turn them but once or twice in the first room, which reduces the labor considerably. The cheeses resting on boards must be turned daily.

During the first week any ripening which occurs is not noticeable, and the cheese remains in the form of hard curd. The surface of the cheese often becomes slightly slimy, and some change in the color can be noticed. Toward the end of this first week the mold can be seen upon looking closely.

During the second week the mold, when once started, grows very rapidly; and in the course of one or two days it covers the cheese completely, giving it a snow-white, cotton-like appearance. This white coat of mold turns to a gray-green within two to four days, and by this time the cheese begin to show actual ripening. The cheese first becomes soft just under the coat of mold, and the ripening proceeds gradually toward the center. On cutting the cheese open a thin layer of softened curd can be observed under the mold. The texture of this ripened part is creamy and soft, just as the whole cheese will be at the time of complete ripening.

If the cheeses remain upon the shelves in the ripening room under proper conditions, as they often do in France, they will ripen completely. But under our conditions, where the air is drier, we have found it necessary to wrap the cheeses during the second week in parchment paper or tin foil. This prevents evaporation and hardening, checks the growth of mold, and promotes the growth of the other organisms, thus hastening the ripening. When the cheeses appear dry and tend to become hard, tin foil seems to give the better result, but in the factories

in the trade parchment paper is nearly always used. The cheeses wrapped in tin foil very commonly develop stronger flavors and softer texture than those wrapped in paper. The time of wrapping affects the kind of cheese produced, and the intensity of the flavor can be partly regulated in this way. If a cheese with a strong flavor is desired, the wrapping must be done when the cheese is only slightly covered with the white mold. The wrapping checks the growth of the latter and promotes a more rapid development of the other mold, *Oidium lactis*. On the other hand, a mild flavor can be obtained by wrapping the cheese after the growth of mold has become luxuriant and has turned blue.

After being wrapped the cheeses are often put in small, round boxes, which they fit tightly and in which they are later shipped to market. These boxes help to maintain the shape of the cheeses, which become quite soft during ripening. At the end of the second week the cheeses are transferred to the second ripening room, where they remain until they are ready for shipment, or, if desired, until they are fully ripe. During the third week the ripening proceeds rapidly, and the cheeses become one-half to two-thirds ripe. On the surface slimy, reddish spots appear, and the cheese begins to give off a characteristic Camembert odor. Between the third and the fourth week the hard curd in the center usually disappears, and the cheese has a creamy, waxlike texture. The delicious flavor found in all Camembert cheese is now evident. A little hard curd may still be found in the center of the cheese, but this will disappear if given time.

Factory methods.

In factory practice in France and also where these cheeses are now made in America they are wrapped and put into boxes as soon as the covering of mold is well started. This is when they are about two weeks old. Instead of ripening further in the factory, they commonly are sent to market at once. Further ripening thus becomes a matter for the dealer. Although this

is the common practice in France, some factories ripen the cheese quite fully to supply a special trade. In other cases dealers establish cellars, where the cheeses are taken out of the boxes, are unwrapped, and are ripened completely on shelves before selling. Others allow them to ripen as they may in the boxes. It seems desirable to recommend that, where domestic factories are supplying our own market, cheeses be ripened far enough to guarantee good results before they are sent out of the factory.

Various defects of cheese

Gassy curd. — In the making of Camembert cheese, as in making any other kind, numerous difficulties are encountered. One of the most common troubles is that arising from gassy curd. In this case the fault generally lies in the milk, being due to gas-producing bacteria. No way has been found in which this difficulty can be absolutely avoided, but it may be partly remedied by increasing the amount of good lactic starter and the development of higher acidity before setting, which will in time overpower the gas-producing organisms. If the curd is kept at a low temperature after dipping, the growth of these gassy organisms is checked to some extent. The gas cannot always be detected in the fresh curd, but sometimes develops later, and if it does the cheese very seldom turns out satisfactorily.

Yeast. — Another difficulty is caused by yeast. The cheeses often become covered with yeast in the making room, although sometimes the yeast makes its appearance after the cheeses have been taken to the ripening room. The surface of such cheeses becomes slimy and sticky, causing the cheeses to stick to the boards, so that when they are turned a thin skin is torn off. In such cases it is difficult to obtain a good growth of mold, for the latter is pulled off with the thin film of yeast, the cheese does not ripen properly, and it often has a strong, bad flavor.

Molds. — Contamination from the other varieties of mold causes considerable trouble. If the cheeses contain spots of green or brown mold, or if a long, fuzzy mold, sometimes with black tops (Mucors), appears, the Camembert mold cannot grow properly, and the result is often a bitter cheese or one with other undesirable flavors. The Camembert mold will sometimes grow over and cover the green and other molds, but this does not prevent them from producing an objectionable flavor. When such infection from foreign molds occurs, the whole equipment should be sterilized, and if possible the walls and floors of the making as well as the ripening rooms should be cleaned and whitewashed.

Dry cheese. — The drying out of cheese is caused by lack of moisture in the ripening rooms, or by too rapid draining of the curd. Such cheeses can often be saved, if the drying out has not proceeded too far, by wrapping them tightly in tin foil.

Wet cheese. — A defect just the opposite of the last is found in wet cheeses. It is caused by too low a temperature of the making room, as well as by too low a degree of acidity of the milk, both of which retard the draining of the cheese. It may also be caused by too high a degree of moisture in the ripening rooms. The ripening of such cheeses is more in the nature of a liquefaction, and the interior becomes so soft that it would run out if the cheese were not kept in a box. There is no hope for such cheeses, as the flavor and texture will never be satisfactory.

Mites. — Serious damage is done to cheeses by the cheese mite, a small insect scarcely visible to the naked eye. These mites crawl all over the cheese and eat up or destroy the mold, so that the cheese will not ripen properly and is practically ruined. The only remedy in such cases is the thorough disinfection of the whole plant.

Skippers. — Another enemy of the cheese is the cheese skipper — the larva of a small fly. The flies lay their eggs on the cheese, and these hatch out in a short time. The skippers remain on

the surface and can be scraped off, but not without spoiling the appearance of the cheese and possibly leaving unhatched eggs. Such cheeses cannot be sold and are practically lost.

Estimated equipment for a factory

The estimated equipment for a factory using about 1000 lb. of milk a day is indicated below. Before building such a plant, however, it is always desirable to visit some dairy establishment where the essential equipment would be as nearly comparable to that needed as possible. This need not necessarily be a Camembert cheese factory. Any properly equipped dairy establishment will give ideas as to the arrangement of steam and water pipes, vats, and the like.

In addition to this ordinary creamery equipment a Camembert cheese factory requires its own special apparatus.

Calculated for 1000 lb. of milk, which will produce 250 cheeses, this will require for the making room:

250 high hoops.
500 low hoops.
150 draining boards (if used in making room only).
150 mats.
Draining table to accommodate 250 cheeses (42 square feet of surface).
Shelf room enough to accommodate 250 cheeses on the second day of draining.

Vats and draining tables should be so arranged as to minimize the labor of dipping. The two ripening rooms must be large enough to accommodate the entire output for about twenty days, *i.e.*, 5000 cheeses. If the cheeses are kept on boards such as are used in the making room, this would require about 500 boards in constant use. These would occupy 700 running feet of shelving. The shelves should be about 5 inches apart. A

rough calculation will show that a total curing space of 14 by 14 by 8 feet would be large enough to accommodate all the cheeses. The arrangement of shelving is a matter of economical utilization of all the available space. Aisles between the shelves should be at least 3 feet wide to give sufficient room to do the necessary work. It probably would require a maker and one helper to run such a factory.

BRIE CHEESE (Doane & Lawson)

This is a soft rennet cheese made from cow's milk. The cheese varies in size and also in quality, depending on whether whole or partly skimmed milk is used. The method of manufacture closely resembles that of Camembert.

This cheese has been made in France for several centuries. Mention was made of it as early as 1407. It is made throughout France, but more extensively in the Department of Seine et Marne, in which it doubtless originated. This department contains Meaux, Coulommiers, and Melun, places noted for their manufacture of Brie cheese, though often under local names. More or less successful imitations of this cheese are made in other countries. It was estimated that 7,000,000 lb. of Brie cheese was sold in Paris during 1900. The export trade is also very important.

The milk used is usually perfectly fresh. It is not uncommon, however, to mix the evening's milk, when kept cool over night, with the morning's milk. Some artificial coloring matter is added to the milk, which is then set with rennet at a temperature of 80° to 85° F. After standing undisturbed for about two hours, the curd is dipped into forms or hoops, of which there are three sizes in common use. The largest size is about 15 inches in diameter, the medium size about 12 inches in diameter, and the smallest size about 6 inches in diameter. These vary in height from 2 to 3 inches. After drainage for twenty-four

hours without pressure being applied, the hoops are removed and the surface of the cheese is sprinkled with salt. Charcoal is sometimes mixed with the salt used. The cheese is then transferred to the first curing room, which is kept dry and well ventilated. After remaining in this room for about eight days, the cheese becomes covered with mold. It is then transferred to the second curing room or cellar, which is usually very dark, imperfectly ventilated, and has a temperature of about 60° F. The cheese remains here from two to four weeks or until the consistency and odor indicate that it is sufficiently ripened. The red coloration which the surface of the cheese finally acquires has been attributed to an organism designated *Bacillus firmatatis*. The ripening is due to one or more species of molds which occur on the surface and produce enzymes which in turn cause a gradual and progressive breaking down of the casein from the exterior toward the center. The interior of a ripened cheese varies in consistency from waxy to semiliquid and has a very pronounced odor and a sharp characteristic taste.

All of the cheeses thus far described are dependent on the action of certain types of microörganisms for the development of their characteristic flavor and aroma. There is another rather large group of soft cheeses, many of them very popular in our markets, which do not undergo a ripening process. These are made up from fresh green curd and are dependent for their flavor and characteristics on the method of manufacture. This group of cheeses includes the Neufchâtel, cottage, cream, club, pimento, and numerous other varieties. For descriptions of this group of cheeses, see Chapter XI.

CHAPTER XI

FARM DAIRYING

WHILE the creamery and cheese factory method of making up the farmer's product has grown rapidly in recent years, there are still many sections and many individual farms where it is desirable for the farmer to make up his own product either into butter or some form of cheese. According to the 1909 census report, 994,650,610 lb. of butter are made on the farm annually. This system has many advantages which the farmer should consider in deciding whether he should deliver his milk or cream to the factory or manufacture it at home. Making up his products at home relieves the farmer of the necessity of daily delivery of his milk, which in many cases is a serious item; it eliminates the factory and the middleman, allowing the farmer to sell his product direct to the consumer, thus receiving the entire retail price; it gives the farmer his by-products such as skim-milk and buttermilk for feeding to his animals; it also has the important advantage of removing the least possible amount of fertility from the farm. To offset these advantages, it involves some additional expense for equipment and a considerable amount of additional labor. It also necessitates the finding of a satisfactory market for the finished product. Which system a particular farmer should follow will depend on local conditions. It of course goes without saying that the farmer who is to make up his own product should have as good cows as he would have if he were to sell his raw milk. This applies both to the total production and the per-

centage of butter-fat. The essential fact to keep in mind is the total production of each cow. Whether he should keep cows which will give a moderate amount of milk rich in butter-fat or those which will give a larger amount with a lower fat test, is a matter of personal choice, provided the total yield of butter-fat is the same.

Whatever disposition is made of his product, the dairyman should be in a position to test his milk and cream for its percentage of butter-fat (see Plate XVI). This is necessary for determining the profitableness of each cow and for the selection of his breeding stock. It is also desirable for the purpose of checking the amount of fat sold. The method of sampling and testing on the farm is given as follows by Hunziker:

TESTING MILK ON THE FARM (Hunziker)

Sampling the milk.

For all practical purposes, excepting official testing and experimental work, it is unnecessary to test milk samples daily. Composite samples may be taken daily and tested weekly and the pounds of butter-fat determined by multiplying the weekly composite test with the pounds of milk produced a week. These samples are best taken with a milk thief, such as the Scovel milk thief, which may be conveniently suspended on the wall of the milk room close to the milk scales. Each sample is taken immediately after weighing the milk. A metal cap or glass stoppered bottle is provided for each cow and bears the number of the respective animal. These bottles are best placed in numerical order on a rack in close proximity to the scales. Each bottle should contain one preservative tablet.

Instead of taking composite samples daily, samples of two milkings a month may be taken and tested. In this case the monthly test is multiplied by the pounds of milk produced a

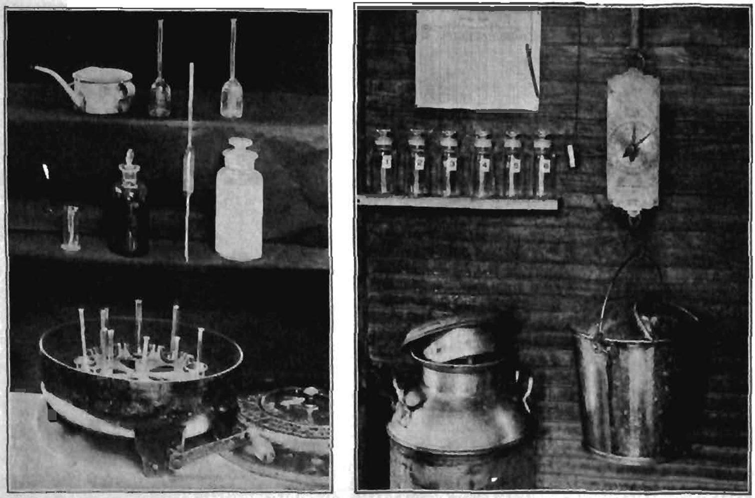


PLATE XVI. — Weighing, sampling, and testing outfit for the farm.

month, in order to determine the pounds of fat of each cow a month.

Freshly drawn milk often contains a great deal of foam. Such milk should be allowed to stand for thirty to sixty minutes before it is measured into the test bottles, in order to give the air incorporated during the operation of milking an opportunity to escape. Then the milk should be stirred thoroughly before pipetting.

Testing the milk (see Figs. 70, 71).

The testing of milk on the farm is accomplished in exactly the same manner as described under the chapter on "Milk Testing." The hand testers on the market range in capacity

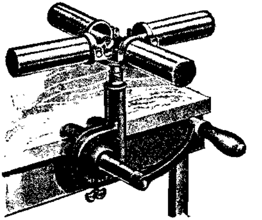


Fig. 70. — A four-bottle hand tester, suitable for a small dairy herd.

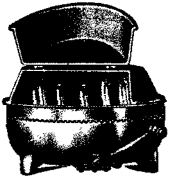


Fig. 71. — A twelve-bottle hand tester, suitable for a good-sized dairy herd.

from two to twelve bottles. The speed is indicated on the crank of the tester. In order to avoid excessive chilling of the contents of the test bottles while whirling in the hand tester, it is advisable to fill the pockets holding the bottles, or the bottom of the castings of the tester, with hot water.

Testing cream on the farm.

The purpose of testing cream on the farm may be twofold. If sweet cream is sold for direct consumption, it is desirable to ascertain the proper richness of the cream. If the cream is

sold to the creamery, the dairyman is in a position to check the accuracy of the creamery's tests.

In either case the directions given under the chapter on "Cream Testing" should be closely followed.

Since, on the average dairy farm, sensitive cream scales are usually lacking, and since there is no particular need of maximum accuracy, the cream may be measured into the test bottle with a 9 cubic centimeter pipette, instead of being weighed. In this case the pipette should be rinsed out twice with warm water and the rinsings transferred to the test bottle; otherwise the test will be too low.

If the cream is measured into the test bottles, care should be taken that the cream, when measured, is not permeated with foam. Cream from the centrifugal separator should not be measured into the test bottle immediately after separation. Freshly separated cream contains considerable foam. If the measuring is deferred for at least thirty minutes after separation, the air thus incorporated can escape and a reasonably accurate test may then be obtained by first stirring the cream thoroughly before sampling.

It should be understood, however, that cream tests made by measuring the cream into the test bottles are only approximate and are not entirely comparable with the more accurate way of weighing the cream which is practiced in the creamery.

METHOD OF SELLING MILK (Truman)

Truman [1] answers the question as to whether a farmer should sell his milk or make butter on the farm, as follows:

That question can best be answered by a comparison of the amount received for 1000 lb. of milk by each method.

One thousand lb. of milk equals 465 quarts. At 3½ cents a quart, its value is $16.27. The value of the same amount of

[1] Storrs Bul. 65.

milk made into butter will depend on the richness of the milk. If it will test 4 per cent of fat, then the 1000 lb. will contain 40 lb. of fat. Under ordinary conditions this will make about 44.5 lb. of butter. This at 35 cents a lb. is worth $15.57. Add to this the value of 800 lb. of skim-milk and 150 lb. of buttermilk, a total of 950 lb. at 25 cents a hundredweight, equal to $2.37, a total of $17.94 for the 1000 lb. of milk when made into butter. This gives a balance of $1.67, in favor of making butter, to say nothing of the value of the fertilizer material in the skim-milk and the profit in having healthy, rapid-growing calves.

It will readily be seen that the side on which the profit will appear will depend wholly on the prices received for milk and butter. If the milk is sold at the farm at four cents a quart and the butter must be sold at 30 cents a pound, then the margin of profit would amount to $2.88 per 1000 lb. of milk, in favor of selling by the quart, provided the milk tests 4 per cent as in the first case.

If, however, the herd in question consisted of well-bred Jerseys, giving milk testing 5 per cent on the average, the result would be somewhat different.

1000 lb. milk	465 quarts
465 quarts @ 4 c.	$18.60
1000 lb. milk testing 5 %	50 lb. fat
50 lb. fat	57 lb. butter
57 lb. butter @ 30 c.	$17.10
950 lb. skim-milk and buttermilk @ 25 c. per cwt.	$2.37
Total	$19.47

This leaves a balance of 87 cents per 1000 lb. of milk, in favor of making butter.

The difference in the total amount received by each method is not large. Which will pay better in any given case will depend on local conditions. Wherever milk must be sold for

less than 4 cents a quart at the farm, it will probably pay better to make butter.

The following statement shows what may be done under the best conditions. A first-class Jersey herd giving milk testing 5 per cent on the average, and a good butter-maker selling his butter for 40 cents a pound, would do business on the following basis:

1000 lb. milk testing 5%	50 lb. fat
50 lb. fat	57 lb. of butter
57 lb. of butter @ 40 c.	$22.80
950 lb. skim-milk and buttermilk @ 25 c. per cwt.	$2.37
Total	$25.17

This leaves a balance of $6.57 per 1000 lb. of milk, in favor of butter-making, over selling milk at 4 cents a quart. This with 10 cows averaging 150 lb. of milk a day would mean just about $6.75 a week or the sum of $351.00 a year.

It may be well to emphasize again the fact that the great value of the skim-milk for calf raising is not allowed for in the 25 cents a hundredweight. That is its actual, estimated food value. But the fact that it is the nearest approach to nature's food for young animals and that with it they make the most satisfactory gains with the least trouble, makes it worth more than double the price allowed.

MAKING BUTTER ON THE FARM

Care of milk and utensils

If butter is to be made on the farm, certain fundamental principles must be kept constantly in mind if satisfactory results are to be obtained, for the success of butter-making does not begin with the churning process or even with the ripening of the cream, but with the quality of the fresh milk. High-

grade butter cannot be made from milk which has not been drawn and cared for under clean conditions. The value of butter is largely dependent on its flavor, and this is determined primarily by the microörganisms which get into the milk and cream before the butter is made. Butter-making actually begins with the milking processs, and in order to obtain good results, the body of the cow should be kept clean, the udder and flank wiped with a damp cloth just before milking, and the milk drawn into a small-topped pail, in order to prevent dust and bacteria falling into the milk. The condition of the dairy utensils is of the greatest importance. A good method for cleaning the utensils is as follows:

1. Rinse with lukewarm water to remove the larger part of the milk.

2. Wash thoroughly with hot water and a good washing powder. It is desirable to use a brush for this process.

3. Thoroughly rinse with clean, hot water.

4. Scald with boiling water or, if steam is available, subject them to steam in a closed chamber for at least thirty minutes. The utensils can be very satisfactorily sterilized by the use of boiling water if care is taken to see that it is actually boiling when used. This process is essential in order to remove the bacteria which adhere to the surfaces of the utensils. Special care should be taken with the strainer cloth.

Method of creaming.

Several methods for separating the cream from the skimmed milk are in use on the farm. The older methods, such as the shallow pan and the deep setting and the water dilution, may be used successfully under proper conditions. It is probable, however, that the centrifugal separator will, in most cases, give more satisfactory results. The advantages of this method of creaming are summarized by Guthrie as follows:

"1. Fewer utensils are used unless there are only one or two cows in the dairy.

"2. The skimmed milk is in better condition for the stock in that it is fresh and warm.

"3. Owing to the fact that the cream aggregates so small a quantity, it can be more carefully cooled and handled than the whole milk could be.

"4. A cream richer in butter-fat can be skimmed. This is essential for good churning. Most of the gravity-skimmed cream is too poor in butter-fat.

"5. Less butter-fat remains in the skimmed milk."

The relative skimming efficiency of the hand-separator, as compared with the older gravity systems, is given by Hunziker[1] as follows:

Method	Percentage of Fat in Skim-milk
Centrifugal separator	0.02
Deep-setting	0.17
Shallow pan	0.44
Water dilution	0.68

If the dairy contains several cows, the saving in cream by the use of the hand-separator will be an important item. Taking all the advantages of this method into consideration, the purchase of a hand-separator will, under ordinary conditions, be a good investment.

Selection of the separator.

At the present time, there are many kinds of hand-separators on the market, many of them selling at very reasonable prices. The mistake should not be made of getting a machine which is too small. Each machine is limited in its capacity, and it should be sufficiently large to do the separating in a reasonable length of time as the additional cost of the larger machine will

[1] Indiana Bulletin 116.

be more than offset by the saving in time and labor of separating. In buying a separator, one should be selected which has the reputation of being durable and capable of close skimming, for the amount of fat left in the skimmed milk is a very important item. There should be no difficulty in operating any of the standard makes of separators if the instructions accompanying the machine are followed. It should stand level on a solid base and be operated at the speed indicated for the particular machine. It is absolutely essential that the separator be kept clean and well sterilized in order to prevent the cream being contaminated.

Variation in percentage of fat from hand-separator.

There are a number of factors which affect the percentage of fat in the cream and skimmed milk from a centrifugal separator. Many dairymen have the impression that the percentage of fat should be constant, but this is not the case. The chief factors affecting the percentage of fat in the cream are as follows:

1. Richness of the whole milk.
2. Variations in the speed of the separator.
3. Temperature of the milk.
4. Rate at which milk flows into the machine.
5. Adjustment of the cream screw.
6. Amount of skimmed milk or water used in flushing the bowl.

Most of these factors are under the control of the operator, and if milk from the same herd is used and all the other factors are constant, the cream should not vary widely in its percentage of fat from day to day. With most separators, the temperature of the milk should be from 85° to 95° for the best results. If the temperature is much lower than this, the separator may not do good work, and a richer cream will be the result, but there will also be a larger loss of cream in the skimmed milk.

The proper speed for each machine is indicated on the crank,

and this speed should be uniformly maintained. If the speed is lowered, a larger amount of cream will result, but with a lower percentage of fat. If the speed is above that specified for the machine, it will give a smaller amount of cream with a richer test. The rate of inflow is controlled by the float between the supply tank and the separator, and if a constant supply of milk is kept in the tank, little attention need be paid to this factor. The percentage of fat in the whole milk has a decided effect on the richness of the cream. The richer the milk, the higher will be the percentage of fat in the cream, while the thinner the milk, the lower will be the fat test of the cream. This may account for sudden drops in the fat test when new milch cows are added to the herd. If the amount of cream separated at one operation is small, the percentage of fat it contains may be materially affected by the amount of skimmed milk or water used in flushing the separator. If the amount of cream is fairly large, the flushing material will have little effect on the test of the cream. The purpose of the cream screw in the separator is to enable the operator to control the richness of the cream, and this can be done within rather wide limits. When once adjusted, however, it should not be changed without good reason. Changes in the cream screw do not account for the daily fluctuations in the percentage of fat in hand-separated cream. These variations are usually due to the variations in the other factors mentioned. It is the common impression that the kind of feed eaten by the cows affects the percentage of fat in the milk, but it has been thoroughly shown by numerous experiments that the percentage of fat in the milk cannot be permanently affected by the nature of the ration. Sudden changes may occur due to radical changes in the feed, but the composition of the milk very quickly goes back to normal. The percentage of fat in the milk is primarily dependent on the breed and the individual cow.

For the best results, cream with a medium percentage of fat

should be separated. If the cream is too rich, it is difficult to handle it, and it may give trouble in the churning process. On the other hand, if it is very thin, it may not churn easily, and the large amount of skimmed milk gives greater opportunity for the development of bacteria which may injure the quality of the butter. Under ordinary conditions, cream testing between 25 and 35 per cent of butter-fat will give the best results.

Care of the cream (Guthrie).[1]

It is difficult to advise the farmer regarding the souring, or ripening, of cream because of varying conditions. It is a question whether or not the average farm butter-maker can afford to use starter, which is a culture of lactic acid producing organisms that should be used in creameries; for, in the first place, few farmers are trained to handle the propagation of these bacteria properly, and, in the second place, the amount of starter that he would use is so small that he could probably obtain better results by spending his time in being more careful in the care of the milk and the cream.

Under ordinary conditions the cream should be cooled to 50° F., or to a still lower temperature, as soon as it is separated. On the second day it should be ripened by raising the temperature to 70° or 80° F. and maintaining that temperature until a mild acid flavor is developed. The cream may be held for several days if the flavor remains good; if it is likely to become strong, it should be churned before reaching this stage.

Sometimes a bitter flavor develops. In order to prevent it, the cream should be ripened as quickly as possible after separation. In this case the ripening process might be conducted as follows: Set the freshly separated cream at about 70° F. When the next separation is made, put the warm cream into the can with the first separation, which is partly soured, and

[1] C. U. Reading Course Bul. No. 60.

stir thoroughly. Continue this process for two or three days. Care must be exercised in controlling the temperature so that the cream will not be over-ripened. On the second and third days, perhaps, the ripening temperature will have to be dropped to 60° or 65° F.

Another method would be to add a small amount of buttermilk to the first batch of cream, which would serve as a starter. The reason why this method should be used in case a bitter flavor develops is that the bitter flavor is produced by bacteria which grow in milk and cream at temperatures of 50° F. or below; the bacteria will not grow even at these favorable temperatures if the cream is sour.

The ripening of cream

"By the ripening of cream is meant the changes it undergoes from the time of separation until it is added to the churn. On these changes depends very largely the quality of butter as regards texture and flavor. The temperature at which cream is held determines the firmness or texture, while the flavor is dependent on the by-products from the bacterial growth.

"The purpose of ripening cream is fundamentally that of giving the butter the desired flavor and aroma, but in addition it increases the ease and efficiency of churning. Cream is ripened in one of two ways:

"First, it sours or ripens as a result of the action of bacteria which are normally present in milk and cream; or,

"Second, it ripens as a result of action of certain kinds of bacteria which are added in what is termed a 'starter.'" (Keithley.[1])

Many times the use of a starter in ripening the cream will be found advantageous. The preparation of the starter is given by Guthrie[2] and Fisk as follows:

[1] Farmers' Bulletin No. 541. [2] C. U. Cir. 13.

Propagation of starter for butter-making (Guthrie and Fisk).

A starter is a material containing desirable bacteria for the ripening, or souring, of dairy products. These bacteria may be purchased of companies whose advertisements appear in the dairy journals. The growing of the bacteria in whole milk or in skimmed milk is known as starter making.

The method presented may sometimes be varied and still good results be secured, but a beginner should not experiment until he fully understands the principles involved in the propagation of starter.

In the cultivation of starter the usual practice is to carry the starter from day to day in a small quantity, which is more carefully handled than the major part. This small amount of starter is termed "mother starter." The choice of containers for mother starter depends largely on conditions and on the preference of the operator. Glass is somewhat preferable, for through it dirt is easily detected and the condition of the curd is readily noted. Two or three bottles should be used, for in pasteurization they may break. Metal holders, as copper properly tinned, or heavy tin, may be used. It is always well to use a sufficient number of containers so that careful selection is possible.

Usually it is necessary to propagate the mother starter two or three times before the flavor of the commercial culture, which is often very disagreeable, will disappear.

The steps in propagation of mother starter are as follows:

1. Take three one-quart bottles or fruit jars.[1]

2. Use fresh, clean milk, which must have a good flavor. It may be either whole milk or skimmed milk. Usually it is advisable to use whole milk, for it is easier to choose desirable samples before milk has passed through the separator than afterward.

3. Fill the containers one-half to two-thirds full of milk. If

[1] Larger receptacles may be used if desired.

they are filled full, it is difficult to prevent contamination from the covers, which are hard to sterilize when the pasteurization is done in hot water.

4. Protect the containers with regular covers (caps or tops).

5. Pasteurize by heating to a temperature of 180° to 200° F. for thirty minutes or longer, and then cool to ripening temperature of 60° to 75° F. Pasteurization may be accomplished by tying a string about the necks of the bottles and suspending them in a pail or vat heated by steam or in a kettle or dish heated on a stove. (If pasteurized over a fire, do not let the bottles rest on the bottom of the receptacle.) Other supports may be used to keep the containers from tipping over. If glass containers are used, the temperature should be raised and reduced slowly in order to prevent breaking.

6. After pasteurization the milk is ready for inoculation. Inoculate in a quiet place where the wind cannot blow dirt and bacteria into this clean seed bed. With dry fingers remove the cover and place it in a clean spot. Pour in all of the commercial culture, or two to ten per cent from the previous day's culture.[1]

7. Ripen at about 60° to 75° F. The first inoculation from the commercial culture should be ripened at about 70° to 85° F. The smaller inoculations require higher temperatures than do the larger inoculations. By experience an operator can soon learn what inoculation and temperature should be used to ripen his starter in a given time. Usually a 1 to 8 per cent inocula-

[1] The amount of ripened starter for inoculation can be measured accurately in a vessel, such as a sterilized cup or spoon, or it can be determined rather closely by the eye. Place the thumb above the milk line in the bottle to be inoculated, in this way measuring the amount to add, and raise the milk line to that mark by pouring in the ripened starter. Be sure that the curd from the previous day is well broken. After inoculation, shake the freshly inoculated sample so as to distribute the bacteria.

tion will ripen a starter in twelve hours at about 65° F. The *temperature must be fairly constant.*

8. The starter is ripe when a curd forms. This curd should be soft and like custard in appearance; it should not be hard and firm.

9. When the starter is ripe, it should be used at once. If this cannot be done, cool to 50° F. or lower. Do not shake the starter before putting it in storage.

10. On examination the curd should be smooth and compact, without gas pockets. Gas shows the presence of undesirable bacteria. A hard, lumpy curd, whey, and high acid show over-ripeness, which is very undesirable. After the state of the curd is noted, shake well to break it into a smooth, lumpless condition. Shake with a rotary motion, being careful not to touch the cap for fear of contamination. Now smell and taste it, but never from the starter container; always pour some of the curd into a spoon or cup and then replace the cover immediately. After smelling, it is best to put at least a teaspoonful into the mouth. Seek for a desirable, clean, mild, acid flavor. The first propagation is likely to be somewhat disagreeable because of the presence of some of the original medium.

On a farm the cream might be handled in the following manner: Suppose the dairyman separates, each half day, 10 lb. of cream testing about 35 per cent butter-fat. On Monday a new starter of about two-thirds of a quart is inoculated from a starter that has been held from Friday or Saturday. The remainder of the held-over starter is put in the 10 lb. of cream. The cream is then set at about 65° F.; it may have to be set in a cooler place before evening. In the evening 10 lb. more cream are added, and all the cream, which is now in the one vessel, is set at about 60° F. On Tuesday morning add the morning's cream and set at 60° to 65° F., as during the day it is more convenient to watch the ripening process than at night. In the evening add the evening's cream and set at 58° to 60° F.,

for by this time there is a very large army of bacteria at work. On Wednesday morning churn the 40 lb. of cream and start the ripening process anew with Wednesday's cream.

It is important not to develop too much acid. The amount of inoculation and the temperature must be managed so as to gain a certain end under certain conditions.

Methods of determining the ripeness of cream.

It is important that the ripening process should be carefully controlled, and that the cream should have the proper degree of ripeness before it is churned. The ripening is caused by the development of lactic acid as a result of the action of the lactic bacteria and the amount of acid development will determine to a large extent the flavor and aroma of the butter. The commonest method for determining the ripeness of the cream on the farm is by its taste and smell. It should have a clean acid flavor without any objectionable flavor. The degree of ripeness may also be judged by the appearance. When the cream is well ripened, it becomes slightly thickened and takes on a more or less glossy appearance. Another method for determining the degree of ripeness is to make an acid test, as is done in regular creamery practice. This test is made by treating a definite amount of the cream with an alkaline solution and an indicator. The cream is measured out into a white cup and the indicator added, after which the alkaline solution is slowly run into the cream while it is being stirred. The appearance of a faint pink tint indicates the point at which the acid in the cream is neutralized by the alkaline solution. The amount of acid present is then calculated from the amount of alkaline solution used. Several methods for making this test are in common use and the apparatus and directions can be secured from the different dairy supply houses. Either Farrington's alkaline tablets (p. 134) or Publow's acid test (p. 300) will give satisfactory results and is easy to use. In many cases, this method of determining the

ripeness of the cream is preferable to using simply the taste and smell.

Coloring the butter (Keithley)

The uniformity in appearance and attractiveness of butter is greatly increased by the color. The most desired color is that usually found in butter produced in June, when cows are having large amounts of green, succulent feed. Butter-makers endeavor to maintain a uniform color throughout the year by the use of "butter coloring." The amount of color varies with the season, but is usually at the rate of one-half to 1½ ounces of color for each 25 lb. of butter, which is about one-half to 1½ teaspoonfuls for each 3 lb. of butter. This color should be added to the cream just after cream has been put in the churn and before churning has begun.

Churning (Keithley)

Churning is a process of removing butter-fat, which exists in minute globules, from milk or cream. This is accomplished by agitating the cream thoroughly, thereby causing the fat globules to come into contact with each other and cohere as a result of concussion. The composition of cream affects the ease of churning. It is composed, as we know, of butter-fat and milk-serum. The percentage of butter-fat affects the proximity to each other of the fat globules which exist in suspension in the serum of milk and cream. Globules are much nearer each other in cream than in milk and nearer each other in 40 per cent cream than in 15 per cent cream. The effect of temperature on these minute fat globules is to harden or soften them, just as it does lard, tallow, and other fats. A low temperature hardens them; a higher causes them to become soft. The ease or readiness with which they adhere to each other upon coming in contact is dependent upon their softness. If they are too firm, they do not adhere readily.

With these few facts in mind, it is well to note the most important factors which influence the process of churning. These factors are:

(1) The percentage of butter-fat in cream.
(2) The temperature of the cream.
(3) Fullness of the churn.
(4) Speed of the churn.
(5) Breed of cows.
(6) Individuality of cows.
(7) Time in the period of lactation.
(8) The feed of cows.
(9) Acidity of cream.

A brief discussion of these factors will bring out more clearly the effect of each.

(1) As noted above, the percentage of butter-fat determines the proximity of the fat globules to each other and affects the chances of their coming into contact during the churning or agitation of the cream.

(2) The temperature of these fat globules determines their softness and the ease with which they adhere and form the small granules. These unite with others until they become visible in granules as large as wheat and corn kernels.

(3) The fullness of the churn affects the amount of agitation which is possible during the revolution of the churn. If the amount of cream is small, it may adhere to the walls of the churn and receive little or no agitation. On the other hand, if the amount is too large, the churn will be so full that very little room will be left for the agitation and concussion.

(4) The speed of the churn also affects the amount of agitation the cream receives. If it is revolved too rapidly, the centrifugal force is sufficient to cause the cream to remain in one end without causing agitation. If it is revolved too slowly, the cream flows from one end of the churn to the other and does not receive agitation or concussion.

(5) The size of fat globules in milk varies according to the breed. The larger these globules, the more quickly and easily they unite. Hence their effect on the time required for churning.

(6) The production of large and small fat globules varies in individual cows. Some produce a larger percentage of large fat globules than others. Hence the churning time is affected by the individuality of the cow.

(7) The stage in the period of lactation is also an influencing factor because of its effect on the size of the fat globules and for other reasons not yet fully understood. In the earlier part of the milking period cows produce milk containing larger fat globules than they do during the later months.

(8) The effect of feed upon churning is due to its effect upon the composition of the fat globules. It is generally conceded that a green succulent feed, like grass, green corn, ensilage, and the like, tends to increase the softness of the fat globules, while a dry feed, such as grain and hay, causes a harder butter-fat.

(9) The acidity of cream probably affects the time and completeness or efficiency of churning. The ripened cream will probably churn in less time and more efficiently than sweet cream; hence, if it is necessary to churn quantities of cream which have been collected from day to day, as is almost universally true in farm butter-making, they should be mixed together a few hours before churning in order that the acidity will be uniform throughout the whole quantity.

While all these factors affect the time and labor required for churning, the most important ones are the percentage of fat in cream, the temperature of the cream, and the fullness and speed of churn. If these four factors are carefully controlled, little difficulty in churning will be experienced. The cream for churning should contain at least 25 per cent butter-fat, should be at such a temperature that it will churn in twenty-five to thirty minutes, giving a firm, granular butter, and should be

sufficient in quantity to fill the barrel churn between one-third and one-half full. The churn should be revolved so as to give the greatest agitation and concussion possible.

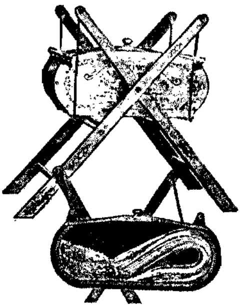
The object of churning (see Figs. 72, 73).

In churning, the butter-fat globules should be massed into granules in order that it can be more easily separated from the other milk constituents. The separation of this butter-fat with ease and efficiency makes churning one of the most important steps in the production of butter either in creameries or on farms. The degree or amount of churning is dependent on the size of granules desired. This varies in practice; but if the purpose in having them a definite size is thoroughly understood, the efforts at controlling their size can be more intelligently made. The purpose or object in controlling the size of butter granules during churning is threefold: (1) removal of buttermilk; (2) more even distribution of salt; and (3) finer grain or texture.

FIG. 72. — The barrel churn.

The buttermilk can be most thoroughly removed if butter is in the form of granules varying in size from that of corn kernels to peas. The massing of butter into lumps as large as a walnut or a man's fist results in the incorporation of buttermilk and makes removal by washing very improbable. Again,

if butter is in small granules, the salt can be more easily distributed and the butter be more uniformly salted. The amount of working necessary is reduced and results in a finer grain and texture. If the butter is in one mass when the salt is added, the working necessary to distribute the salt will usually injure the body. The size of the granules can be controlled by stopping the churn frequently after the butter breaks. The churn should be stopped when butter is in granules as large as corn kernels or peas.



INSIDE VIEW

FIG. 73. — The Davis swing churn.

Washing the butter (Keithley)

After the churning has been completed, the buttermilk should be drawn off through a fine-meshed strainer to prevent loss of small particles of butter. When the buttermilk has been removed, the butter should be washed with cold water which is a few degrees colder or warmer than the buttermilk was. This temperature depends on the butter. If it is too soft, use colder water; if too firm, use warmer water. The reasons for washing butter are three: (1) to remove the greater part of the buttermilk, and in many cases to improve the flavor; (2) to improve the keeping quality; (3) to "firm" or harden the butter so that it can be more easily handled and neatly packed. The method of washing depends somewhat on the kind of churn in use, but the primary object is the same, viz., removal of the buttermilk. In a barrel churn, if an amount of water equal to that of the buttermilk is used, eight to twelve revolutions is generally suffi-

cient to remove the buttermilk. When washing is completed, the butter should still be in the granular condition.

Salting the butter (Keithley)

After drawing off the wash water, the granular butter should be salted. The amount of salt necessary varies. If the reasons for salting are kept in mind, the amount necessary can be readily determined. There are three reasons for salting: (1) improvement of the flavor; (2) satisfying market demands; (3) serves more or less as a preservative.

There are several methods in use among butter-makers for determining the amount of salt to be added to butter. In creameries salt is usually calculated on the butter-fat basis, *i.e.* from the weight of cream and percentage of butter-fat the pounds of butter-fat are calculated, and for each pound of butter-fat a definite amount of salt is added. This amount varies from ½ oz. to 1½ oz. a pound, dependent on demands of the market. In the larger dairies, where from 50 to 500 lb. are made a week, probably the most common method is to weigh the granular butter after washing has been completed, and add a definite amount of salt for each pound of butter. This amount varies in different localities from ½ oz. to 1½ oz. to a pound. When this practice is followed, the salt should be sifted evenly over the granular butter by use of a fine-meshed sieve. This prevents the addition of lumps of salt, which would be dissolved and distributed with difficulty.

In the small farm dairies, where from 5 to 10 lb. are made a week, it is usually the practice to estimate the weight of butter and guess at the amount of salt necessary. This practice is not to be recommended on account of the great lack of uniformity in salting which results. Either the practice followed in creameries or the larger dairies should be used. Weighing both the butter and salt is probably the more practical.

Working the butter (Keithley) (see Figs. 74, 75, 76)

After the addition of the salt, the butter should be worked. The purposes of working are: (1) to distribute the salt; (2) to produce a compact, firm, close-textured body; (3) to expel moisture and buttermilk.

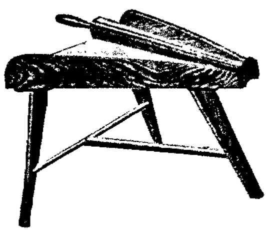


Fig. 74. — Lever butter-worker.

The amount of working necessary to distribute the salt depends on the granular condition of the butter and salt. If the butter is in lumps or is very firm, more working is required than if butter is in small granules. If the salt is not well pulverized and fine grained, it is hard to dissolve and distribute. It dissolves and is distributed more easily in a fairly soft butter than in a very firm, hard butter.

Fig. 75. — Original Waters' butter-worker.

The desired body is also dependent on the granular condition and firmness of the butter. When the granules are small and very firm working requires more effort. When they are too soft the butter requires less working, but is very likely to be lacking in texture, *i.e.* without a granular appearance when the broken surface is examined.

Three points should be observed in determining whether

butter is worked sufficiently: (1) it should present a firm, glossy appearance; (2) the texture, especially at later examinations, should resemble the granular structure of broken end of steel rod; (3) there should be no grittiness due to the unevenly distributed or undissolved salt. This can be determined by taking a small piece of butter between the teeth and biting into it repeatedly. Any grittiness will soon be observed.

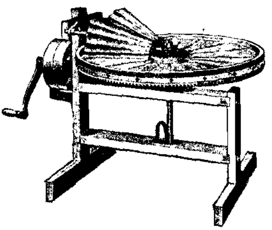


FIG. 76. — Mason butter-worker.

Insufficient working is generally shown by a mottled appearance in color on the cut surface. This is largely due to an uneven distribution of salt. Overworking is usually shown by a poor grain or texture. This results in a salvy condition and injures the keeping quality. The aim of butter-makers should be to produce a high-grade article that is uniform week after week in flavor and composition. This can be done by careful methods in ripening, salting, and working.

Printing and packing butter (Keithley) (see Fig. 77)

The printing and packing of butter is the first and fundamental step in getting it on the market or before the consumer, and should be given careful attention. The greatest lack of uniformity in farm butter is probably that apparent in package or printing. The objects to be attained are: (1) convenience in handling; (2) attractiveness for the consumer; (3) source of advertising to the producer.

Success in making the butter attractive, convenient to handle,

and an advertisement in itself will make profit more probable if care be taken in the production of a good quality of butter. *With such attributes butter can usually be profitably marketed.*

The packages now in use among farmers are crocks, fiber boxes, parchment papers and cartons, dishes, buckets, pans, and the like. The use of some of these packages makes attractiveness and convenience impossible. The most desirable and attractive forms of packages are the 3-, 5-, or 10-pound earthen crocks and the 1- or 2-pound prints wrapped in parchment papers. These wrapped prints are in some cases inclosed in pasteboard cartons or boxes. The name and address of the producer and a brief statement concerning the butter is usually printed upon the paper or carton. This serves as an advertisement and makes a trade-mark possible whereby the public may know what to call for and know whether the butter received is the butter that was asked for. This should lead to an increased demand for that particular product.

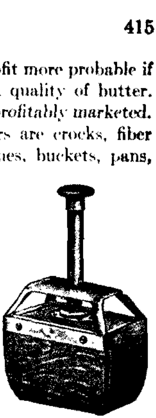


FIG. 77. — Hand butter printer.

Marketing the butter (Keithley)

The original and ultimate object in the production of farm butter, as in any other product, should be production at a profit. This profit, being dependent on the marketing, should make the efforts toward securing a suitable market greater than is usually the case. The objects to be gained in marketing are: (1) patrons who appreciate and are willing to pay for a butter superior in quality and appearance; (2) a constant steady market; (3) satisfied customers, which will result in an increased demand.

With these points in mind it is well to state the kinds of market that are available and which are being profitably taken advantage of in different sections of the United States. These are classed as follows: (1) private customers, *e.g.*, individuals, hotels, and restaurants; (2) selected grocery stores; (3) summer hotels in certain localities; (4) commission houses in near-by cities.

BUTTER SCORE-CARD

Sample.................... *Date*....................

REMARKS:

Flavor.....	45	.....	....
Body......	25	.....	....
Color......	15	.....	....
Salt.......	10	.....	....
Package ...	5	.....	....
TOTAL...	100	.....	

RECOMMENDATIONS:

....

....

....

....

....

....

Salt...... %

NAMES OF JUDGES ....
....
....

Water.... %

FLAVOR

Desirable

Clean, Creamy — pleasant bouquet, Aroma.

Undesirable

DUE TO CREAMERY CONDITIONS

Dirty (*name cause if possible*).
Churn, Vat, Refrigerator, Separator, etc.
Woody, Rancid,
Poor starter, Too high ripening
Oily, temperature.

DUE TO FARM CONDITIONS

Dirty (*name cause if possible*).
Pails, Cans, Barn, Milkhouse, etc.
Weedy (Name weed if possible).
Barny,
Cowy,
Feedy (Name feed if possible),
Silage, Hay, Grain.

DUE TO EITHER CREAMERY OR FARM CONDITIONS OR BOTH

Flat, Cheesy,
Smothered, Bitter,
Fishy, Metallic,
Turpentiny, Dirty Strainer.

BODY

Desirable

Waxy Medium Grain (in length).

Undesirable

Weak, Too much water,
Tallowy, Not enough water,
Milky Brine, Water not well incorporated,
Greasy,
Short Grain, Leaky.

COLOR

Desirable

Uniform, Medium Shade (June or Straw).

Undesirable

Mottled, Wavy, Too light,
Streaked, Too high, Not clear.

SALT

Desirable

Well dissolved, Medium in Amount.

Undesirable

Too high, Gritty,
Too light, Not well distributed.

PACKAGE

Desirable

Neat, Clean, Attractive.

Undesirable

Not suited to market, Not finished,
Poorly packed, Moldy,
Cheap, Not full,
Dirty, Damaged.

Holding butter for winter use

It frequently is desirable on the farm to store butter during the summer for use in the winter when the supply is scarce and the price high. In this way it is frequently possible to effect quite a saving and at the same time provide a supply of high-grade butter for the entire winter. Guthrie gives the method for storing butter for home use as follows:

"The procedure of manufacturing butter and of packing it should be as follows: Make the butter from cream that contains a low acidity, or preferably from cream that is perfectly sweet. This cream should be pasteurized at 145° F. for thirty minutes. After pasteurization, it should be cooled to 48° or 50° F. and it should be held at approximately this temperature for at least three hours before churning. Care should be exercised

in washing the butter, and then sufficient salt should be added to give it the desired taste. A high percentage of salt in butter is not advantageous in the keeping properties.

"There are two methods of packing butter for this purpose. In either case a stone jar which has been thoroughly washed and scalded is the best receptacle. The butter may be printed in 1-pound bricks and then submerged in a salt solution, or it may be solidly packed. In case it is put into brine, this brine should be made by first boiling the water and then a sufficient amount of dairy salt added to make a brine that will float an egg. The prints may be wrapped in parchment or they may be submerged without being wrapped. It is a little more convenient in removing the butter from the brine and in its preparation of the table to have it wrapped. In order that the butter be kept submerged in the brine, it is well to place a plate or a wooden circle over the top of the butter and to weight it down with a stone. If a wooden circle is used, odorous woods should be rejected.

"If it is desirable to pack the butter solidly in a jar, it should be covered with a white cloth which has been thoroughly scalded and then about one-eighth inch of salt should be spread over the cloth. The salt protects the surface of the butter and the cloth aids in removing the salt.

"The next step consists in storing the butter at low temperatures. It will usually hold nicely when placed on the floor of a cool cellar."

CHEESE-MAKING ON THE FARM

During the last half century, the cheddar cheese industry of this country has been largely transferred from the farm to the factory. Yet in spite of this change there are still many farms where cheese can well be made, as is shown by the fact that about nine and one-half million pounds of cheese were made on farms in 1909 according to the United States Census report.

There are also several varieties of soft or fancy cheeses which may profitably be made on the farm, some of these from skim-milk, and whose manufacture works well with farm butter-making or the sale of cream.

The methods applicable for cheese-making on the farm differ somewhat from those used in the factory. Those suitable for making cheddar or American cheese are given by Larsen and Jones as follows:

Methods for making cheddar cheese on the farm (Larsen [1] and Jones).

For cheese-making it is extremely important that the milk be produced under the most sanitary conditions, and that it be cooled as low as possible without freezing at once after it is milked.

It is also important that the milk be made into cheese at least once each day. It is best if the cheese can be made at once after milking.

Coagulate milk with rennet.

A regular cheese-vat having a jacket for heating and cooling the milk is the best as a container of the milk. Such a vat is not always obtainable on the farm. A clean sanitary tub, or even a wash boiler, may be used. The milk should all be strained through two thicknesses of cheesecloth as it is poured into the cheese tub.

Then bring the whole amount of milk to a temperature of 85° F. If the milk is heated on a stove, great care should be taken not to heat too rapidly, nor to too high a temperature. A good way is just to warm a small amount and then mix it with the whole. No part of the milk should be heated to a higher temperature than 120° F. A higher temperature than this will interfere with the proper curdling of the milk.

[1] So. Dak. Bul. 164.

If the milk from a whole day is made into cheese, then it is sufficiently ripe to "set" as soon as the proper temperature has been obtained. On the other hand, if the milk is made into cheese shortly after milking, then the milk should stand not less than an hour at the 86° F. temperature to ripen before the rennet is added. In case this cannot be done, a small amount of good sour milk, buttermilk, or whey may be mixed with the milk from which the cheese is to be made. Do not add more than 2 per cent or more than 2 lb. of the good sour milk to each 100 lb. of cheese-milk.

The next step is to add the color. Butter color will not do for this. It must be cheese color. The amount to add will vary with the strength of the color and with the demands of the market. The cheese should not be red, nor should it be white. A medium yellow color is liked by most cheese consumers. Add from one-half to one teaspoonful ($\frac{1}{16}$ to $\frac{1}{8}$ ounce) to each 100 lb. of milk, and mix thoroughly.

The amount of rennet to add also varies with many conditions, the chief ones of which are the acidity of the milk, the strength of the rennet, and the temperature of the milk. The amount of rennet added should be such that the milk curdles in twenty to thirty minutes. This amount will be about one ounce to 250 lb. of milk.

When the rennet has been measured out, it should be mixed with about 40 times the amount of cold water. When ready to add the diluted rennet, stir the milk. This is done so that the rennet will be completely mixed before it has a chance to act on any one part of the milk. Continue to stir the milk for about two minutes. Do not disturb the milk while coagulating.

Cutting the curd.

The curd should not be cut till it is reasonably solid. To test when it is ready, insert the forefinger into the curdled milk at an angle of 45 degrees, then slowly lift the finger straight up. If the curd splits smoothly over the finger, then it is ready to

cut, while if it breaks into small pieces and ragged, then it is too soft to cut.

Usually, the time required for the curd to set, from the time the rennet is added, is from three-fourths to one hour. About twenty minutes is required for the milk to curdle. Fully as much time will be required for the curd to set until it is ready to cut.

Special cheese knives are made for cutting the curd into small squares. For making cheese on a small scale on the farm these are not necessary. A homemade, long-bladed wooden knife may be used. The curd should be cut lengthwise and crosswise into small cubes. A wire toaster is a convenient tool for completing the cutting of the curd into cubes not over one-half inch in diameter. The particles should be as uniform in size as is possible to obtain an even cook or even heating.

Heating the curd.

The curd is not "cooked." It is gradually heated to expel the moisture, and to make the curd firm. At this stage there will be considerable whey. Dip some out and heat it to a temperature of 135° F. Then gradually pour it back and mix it very gently with the contents of the vat. Do not allow the curd to mat. Keep the particles separate by gentle stirring. If roughly handled, while the curd particles are soft, much of the fat will be lost in the whey.

Pour in only enough hot whey to raise the temperature of the whole 3 or 4 degrees, then gently stir for five minutes. Add hot whey again to increase the temperature 3 or 4 degrees more and stir five minutes. Continue this until the temperature has reached about 100° F. It will thus require about thirty to forty minutes to bring the temperature from 86° F. to 100° F. Allow the curd to remain at this temperature till the curd is cooked through. When this is done, the curd is so hard that when a handful of it is squeezed, and when the grip again is released, the curd particles will not stick together.

After the curd has reached this stage, allow it to remain in the whey for about thirty to forty-five minutes more. This is done to develop acid in the curd. In the manufacture of cheddar cheese in the factory, the whey is drawn and the curd is piled to develop the proper amount of acid. On the farm this method is not practicable. There is a slight danger of over-cooking the curd by the modified method.

The curd thus left in the whey should be closely watched so it does not get too much acid. A curd that has developed too much acid produces a dry cheese, lacking in flavor. A cheese that contains too little acid is likely to develop gas when put into the curing room. The curd may be tested occasionally on a piece of hot iron. When it strings about one-half inch, then draw the whey from the curd.

While the curd is developing acid in the whey, it must not be allowed to mat. Stir it just enough to keep it from matting.

When the proper amount of acid has been developed, then drain off the whey. The curd should be gently stirred to aid in getting the whey effectively drained away from it.

Preparing the cheese for the press (see Figs. 78, 79).

When the curd is ripened as mentioned above, "the milling process," or subdividing the curd, is done away with. The curd is ready for the salting as soon as it has been well stirred and the whey is thoroughly drained off.

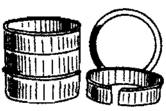


FIG. 78. — A hoop for making "Young America" cheese, a size suitable for the farm.

About 1 lb. of salt should be added to the curd for each 300 lb. of milk used. The amount of salt the maker should regulate according to the quality of cheese he wishes to make. Too much salt makes the cheese too dry and it retards the curing. Too little salt causes the cheese to ripen too fast. The salt should be thoroughly mixed with the curd to secure uniform distribution.

If cheese is regularly made on the farm, special hoops should be purchased. The Young America hoop is probably of most suitable size for farm cheeses. These hoops make a cheese that is seven inches in diameter. The height is variable. The most suitable weight to make a Young America cheese is about 10 lb.

If a cheese is made only now and then, a hoop may be made from a small tin pail having straight sides and a diameter of about 7 to 8 inches. There is no objection to a hoop of greater diameter. If such a hoop is used, holes should be made in the end to permit draining of the whey during pressing.

The hoops should first be thoroughly cleaned. Then place some cheesecloth within the hoop. Make the folds as smooth as possible. The curd is then placed in the hoop. Special hoop liners or bandage and circles should be purchased if the hoops of regular sizes are used.

Care should be taken to keep the curd warm. Do not expose it too much to the cold air. Cold curd will not unite when put into the press.

When the curd has been placed in the hoop, then put the follower (circular board) on and place it in the press.

Pressing the cheese.

If much cheese is made on the farm, one of the regular cheese presses should be purchased. If only a small amount is made, a homemade press will serve the purpose. A press such as is illustrated will do the work. An old wagon tongue will serve the purpose of the lever. One end may be fastened to the side of a building with a strong set of hinges or it may be just inserted under a block of wood fastened to the wall.

In pressing the cheese in such a press, care should be taken to keep the lever level, otherwise the cheese will not be regular in shape.

When the cheese is first put to press, very little pressure should be applied. The weight should be close to the cheese.

The pressure is gradually increased by moving the weight toward the end of the lever. In case the curd should be a little cold, greater pressure should be applied when first put into press. A final pressure of about 500 to 800 lb. should be applied to the cheese. This does not mean that the weight should be so heavy as that.

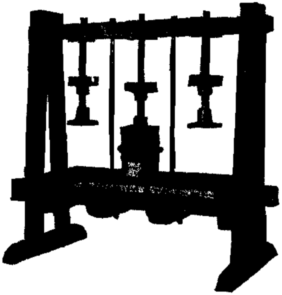


Fig. 79. — A convenient hand cheese press.

When the cheese has been in press about one hour, it should be turned, and the bandage or lining should be adjusted. If the cheese does not unite well, apply a little warm water. In another two hours, turn the cheese again. The cheese should remain in press not less than twenty-four hours. In case the cheese does not unite well in pressing, it may be soaked in warm water while still in the bandages, then put back in the press.

Curing the cheese.

So far, the cheese is only half made. The curing is a very important part of cheese-making. The temperature and humidity of the curing room should both be under reasonable control. The curing room must not be too dry. This will cause the cheese to dry too quickly, and to crack. There should be no draft in the curing room, yet it should permit of ventilation.

If the curing room is too dry, the floor of the room may be sprinkled with water or a wet sheet may be hung up in the room.

If it is desired to have the cheese cure quickly, then the temperature may be kept at about 70° F. The best cheese, however, is obtained from slow curing in a cold room. A temperature between 50° F. and 60° F. produces good results.

A cellar is probably the best available place for a curing room on the farm.

When the cheeses are first put in the curing room on the farm, they should be turned daily; and during the ripening process, should they become moldy on the surface, the cheese and shelving should be washed thoroughly with a strong salt brine.

Methods of making some of the soft cheese (Fisk)

The method of manufacture here presented for each kind of cheese is the one that was found to give the best results.

There are certain requirements which must be complied with in order that the cheese shall be of prime uniform quality: (1) The cheese must have a good flavor. It can be of no better flavor than the milk from which it is made, and therefore there must be a supply of good milk. (2) The room in which the cheese is made must be so constructed that the temperature can be controlled. This is necessary in order to insure a uniform development of lactic acid. (3) A good, clean starter must be used.[1] The starter not only hastens the development of lactic acid, but also tends to correct or overcome bad flavors in the milk. (4) The equipment must include an acid test, by means of which the amount of acid in milk and in whey can be quickly determined at the different stages of manufacture.

Pasteurization.

All the soft cheeses can be greatly improved in flavor, body, and texture by pasteurizing the milk. Practically the same results can be accomplished by the use of a homemade pasteurizer as by the improved machines for pasteurizing.

[1] See page 403.

One very easy method of pasteurizing milk, when one of the especially constructed machines is not available and only a small quantity of milk is to be pasteurized, is to cut off the upper part of a barrel and insert a steam pipe in the barrel (Fig. 80). The can of milk to be pasteurized is put into the barrel and the steam is turned on. Care should be taken that the milk is not heated to too high a temperature, and it should be stirred frequently in order to insure even temperature and to prevent a cooked flavor in the product. The stirring may be done with either a dipper or an especially constructed stirrer; in either case the implement should be left in the can and the can kept covered as much as possible while the milk is being heated and cooled, as otherwise contamination is likely to occur. The improved pasteurizers have a mechanical stirrer.

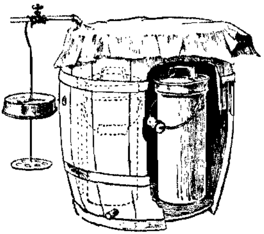


FIG. 80. — A convenient equipment for pasteurizing milk or making starter.

An arrangement by which the milk may be stirred without removing the cover is shown in Fig. 81, but in order to take the temperature — which should be taken with a sterile thermometer — it is necessary to remove the cover. This apparatus also makes a very good outfit for the preparation of starter.

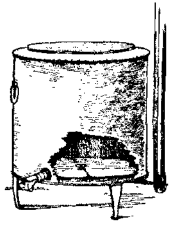


FIG. 81. — Pasteurizer with mechanical agitator.

By whatever method pasteurization is accomplished, the milk should be heated to a temperature not above 140° F. for

fifteen minutes, and then immediately cooled to the setting temperature. If heated to too high a temperature, the milk will have a very undesirable cooked flavor, and this will be imparted to the cheese.

Pasteurizing the milk tends to overcome the difficulties encountered in making cheese from gassy milk. Also, cheese made from pasteurized milk is much smoother in texture than cheese made from raw milk, and the yield is slightly greater.

The method of manufacture is the same whether or not the milk has been pasteurized, except that less starter is used with pasteurized milk.

Pot cheese.

Pot cheese is the kind of cheese usually made by the housewife by souring skim-milk on the stove. It is now more extensively made in dairy plants than was formerly the case. By the use of a thermometer and a clean commercial starter, a product more uniform in quality than would otherwise be possible will be obtained.

Method of manufacture. — The skim-milk as it comes from the separator should be at a temperature of from 85° to 90° F. It should be run into a vat and should not be allowed to cool below 80° F.; held at this high temperature it will sour or thicken much more quickly than if held at a lower temperature. The souring can be accelerated by the use of a starter, which may be added at the rate of from 0.5 to 5 per cent of the skimmed milk used, depending on the amount of starter that can be made. .Generally, the more starter that can be added, the more rapid will be the coagulation and the better will be the flavor of the cheese. As soon as the milk has thickened, the curd is ready to be broken up and separated from the whey. This separation is hastened by the application of heat. Usually the temperature of the curd is raised slightly before it is broken up; since this makes the curd firmer, there will be a smaller loss of curd particles in the whey. The curd

may be cut with coarse cheddar cheese knives or broken with a rake. The temperature of the curd should be raised very slowly, at least thirty minutes being taken to reach the desired final temperature. No set rule can be given as to the exact temperature to which the curd should be heated. The temperature should be raised until a point is reached at which the curd, when pressed between the thumb and the fingers, will stick together and not go back to the milky state. This temperature is usually from 94° to 100° F., but the cheese-maker must use his own judgment in this respect. If the curd is heated too much, it will be hard and dry; on the other hand, if it is not heated sufficiently, the whey will not separate from the curd and the curd will be very soft and mushy. When the curd has been heated sufficiently and has become firmed in the whey, it should be removed from the whey. This may be done either by letting down one end of the vat and piling the curd in the upper end, or by dipping out the curd into a cloth bag and allowing the whey to drain, which it does very rapidly.

When dry, the curd may be packed in milk cans and shipped, or put into cloths and pressed into small bricks weighing about 2 lb. It is usually made into cottage cheese, either at the factory or after shipment.

Yield. — The yield from 100 lb. of skimmed milk varies from 14 to 19 lb. of cheese. The yield varies with the moisture-content of the cheese, being in general greater for cheese with a high moisture-content. Too much moisture or whey should not be left in the curd, however, as this would render it too soft to be handled.

Qualities of pot cheese. — Pot cheese should have a clean, pronounced acid flavor. It should be grainy in texture, but free from hard, dry lumps. Since no attempt is made during the manufacturing process to control the acidity, the cheese will sour or spoil in a short time.

Baker's cheese.

Baker's cheese is best made from skimmed milk by the use of commercial starter and rennet extract. This process is longer than that for pot cheese, because it takes longer to get a coagulation and longer for the whey to drain from the curd. The name is due to the fact that the cheese is used to a considerable extent by bakers as filling for pies and cakes.

Method of manufacture. — The milk from the separator should be cooled and held at such a temperature that the acidity will not be above 0.2 per cent at the time when the starter and the rennet are added. If the milk is fresh and sweet when separated, it will not have to be cooled below the setting temperature of 75° F. The starter and the rennet should not be added until late in the afternoon, because if they are added too early the coagulation period will be too long. The time from setting to dipping should be about twelve to fifteen hours. At the time when the starter and the rennet are added, the milk should be at a temperature of 75° F.; and this temperature should be maintained until the curd is dipped.

Sufficient starter should be added in the afternoon so that the acidity of the whey separating from the curd the next morning at the time of dipping will be from 0.45 to 0.5 per cent. Generally, from 1 to 3 lb. of starter for every 1000 lb. of milk is sufficient. The amount of starter to be used depends on the acidity of the milk, the temperature at which the milk is held during the coagulating period, the acidity of the starter, and the length of time allowed for coagulation.

If the milk is too sweet, the starter may be added some time before adding the rennet; usually, however, the rennet is added as soon as the starter has been thoroughly distributed through the milk. The rennet extract should be added at the rate of ¼ to ½ ounce for every 1000 lb. of milk. Before it is added to the milk the rennet should be diluted with cold water

in the proportion of forty parts of water to one part of rennet extract; this checks the action of the rennet so that it can be evenly mixed with the milk. The action of the starter and the rennet will coagulate the milk in a short time; it should be left undisturbed, however, until the following morning, when the coagulation will be firm and the whey will have begun to separate.

The whey separating from the curd the following morning should have an acidity of from 0.45 to 0.5 per cent. If the acidity is above this amount, further development should be checked by the addition of salt, since too much acid is very likely to cause an acid cheese; if the acidity has not reached this point, the curd should not be disturbed until it does, as an insufficient amount of acid causes difficulty in separating the curd and the whey.

The separation of curd and whey is best accomplished by dipping them on to a large cloth in a curd sink, allowing the whey to drain away (Fig. 82). The curd should be rolled from the cloth (Fig. 83, page 436), in order that the pieces of curd next to the cloth will not become too dry and also that the whey will have a better opportunity to escape. The expulsion of the whey can be hastened by the application of pressure. This may be brought about by covering the curd with the cloth, placing a board on top of the cloth, and setting cans of water on the board; or the curd may be placed in cheddar-cheese hoops and pressed. The curd should be stirred occasionally, so that the particles

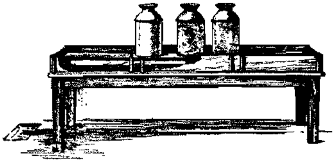


FIG. 82. — Draining rack with milk cans full of water used for pressure.

next to the cloth will not become too dry, as this causes the formation of hard lumps which will not mix with the remainder of the curd and a lumpy texture results. When sufficiently dry, the curd is usually packed for shipment in milk cans or in specially constructed cans.

Yield. — The yield of baker's cheese is from 15 to 21 lb. for 100 lb. of milk. Pasteurization increases the yield by about 2 lb. of cheese for 100 lb. of milk. It is very difficult to compare yields of this cheese because the yield is in proportion to the water content, which varies within wide limits.

Qualities of baker's cheese. — Baker's cheese should have a very mild acid flavor. It should be smooth in texture and entirely free from grains and lumps. It will keep for about a week if stored in a cool place.

Cottage cheese.

Method of manufacture. — Cottage cheese is very easily made from either pot cheese or baker's cheese. The manufacturing process is the same in either case. The cheese is broken up and salted evenly, two ounces of salt being used to 10 lb. of curd. Cream or butter is usually mixed with the curd, the amount depending on the price to be received for the cheese. Usually, the greater the amount of fat added, the higher will be the price received for the cheese.

Composition. — In the table is shown the composition of cottage cheese made by adding heavy cream, testing about 50 per cent fat, to the curd at the rate of one pound of cream for each one hundred pounds of skimmed milk from which the curd was made. The table shows that, while the percentage of fat varies somewhat, the percentage of moisture varies between wider limits. The composition of pot cheese and of baker's cheese is about the same as that of cottage cheese, except that the two former cheeses contain only a trace of fat.

Composition of Cottage Cheese

	I	II	III	IV	V	Average
Water	72.8	74.4	74.2	70.9	71.7	72.8
Fat	4.5	3.5	4.0	3.0	3.5	3.7
Protein	16.9	17.5	16.9	20.7	19.5	18.3
Acid (calculated as lactic acid)	2.2	2.0	2.1	2.2	2.0	2.1
Milk sugar	1.8	0.8	1.4	1.2	1.8	1.4
Ash	1.8	1.8	1.4	2.0	1.5	1.7

Marketing. — Cottage cheese is marketed in several different ways. The commonest method of marketing, and by far the cheapest, is to mold the cheese into prints or balls of various sizes and wrap it in parchment paper. If this is to be done, a good practice is to measure each print by an ordinary 1-pound butter mold, care being taken that the mold is full and that there are no air spaces in the cheese. The print of cheese can then be cut in two and wrapped, making two half-pound packages — a very desirable size for family use. Paper cut six by eleven inches is required for wrapping packages of this size. The cheese may be put up in paper cartons of various sizes, but these are rather expensive, and are very likely to absorb whey and thereby become so soft that they cannot be handled. In a few cases the cheese is put into glass jelly tumblers, but this is a very expensive method and one not commonly used.

Qualities of cottage cheese. — Cottage cheese chould be elean in flavor, resembling fresh butter in this respect. It may or may not be grainy in texture, but it should be free from hard, dry lumps. If it is made from baker's cheese it will be smooth in texture, but if made from pot cheese it will be grainy.

Defects in pot, baker's, and cottage cheese.

Pot cheese, baker's cheese, and cottage cheese are liable to

the same kinds of defects. These, with their causes and remedies, may be classified as follows:

I. Defects in flavor.

(a) Acid flavors (indicated by sour taste and smell).

Causes.

1. Too high acid content of milk used.
2. Too long a period from setting to dipping.
3. Too much starter.
4. Too high a temperature at setting.

Remedies.

1. Use of sweeter milk.
2. Dipping of curd when the whey shows from 0.45 to 0.5 per cent acidity.
3. Use of less starter.
4. Setting at lower temperature.
5. Addition of salt to the curd as soon as it is dipped, in order to check acid development.
6. More rapid working of curd.

(b) Food flavors (characteristic of the foods eaten by cows).

Causes.

1. Access of cows to such foods as turnips, onions, leeks, garlic, weeds, and the like.
2. Exposure of milk in an atmosphere where any of these foods are exposed.

Remedies.

1. Cows must not be allowed to eat the foods named.
2. Aëration in pure air will help to remove odors from the milk.

(c) Unclean flavors (under this head may be included any flavors that are not clean or that are foreign to the cheese and not mentioned above. These flavors may be caused in a number of ways. Only the leading causes are mentioned).

Causes.

1. Use of a starter of bad flavor.
2. Gassy milk.
3. Careless milking.
4. Use of dirty milk cans.
5. Milk not being properly cooled after it is drawn from the cow.
6. Dirty factory conditions.

Remedies.

1. Use of a starter of good flavor.
2. A supply of clean milk.
3. Cleanliness of everything that comes in contact with the milk.

II. Defects in body and texture.

(a) Dry and mealy textures (shown by cheese being too hard, firm, dry, and mealy).

Causes.

1. Too little moisture in the cheese.
2. Too high development of acid.
3. Use of too much rennet extract.

Remedies.

1. Incorporation of more moisture into the cheese.
2. Prevention of development of so much acid.
3. Use of less rennet extract, and provision for a longer coagulating period.

(b) Lumpy texture (shown by hard lumps of various sizes in the cheese).

Causes.

1. Uneven drying of the curd.
2. Uneven coagulatiou.
3. Too high a temperature during process of manufacture.
4. Too much variation in temperature.

Remedies.

1. Occasional stirring of curd so that it will dry evenly.
2. Even mixing of rennet through the milk.
3. Provision of a room in which the temperature can be controlled.

(c) Soft, pasty texture (shown by cheese being soft and sticky).

Causes.

1. Cheese not sufficiently dried.
2. Pasteurization of milk at too high a temperature.
3. Use of too much cream.

Remedies.

1. More thorough drying of the curd.
2. Pasteurization of milk at a lower temperature.
3. Use of less cream.

Neufchâtel cheese.

As its name indicates, Neufchâtel cheese originated in France. It is now extensively made in this country, but by different methods from those originally employed in France. It may be made from either whole milk or partly skimmed milk, pasteurized or unpasteurized.

The secret of success in making Neufchâtel cheese, as well as

the other varieties of soft cheese, lies in having the temperature and the acidity under control. This cheese has never been successfully made in a vat because the temperature of the curd throughout cannot be controlled. The curd nearest the sides and the bottom of the vat will be colder or warmer, as the case may be, than that in the center of the vat. This will result in uneven coagulation and uneven acid development.

The milk for the manufacture of this cheese must be of a clean flavor. Too much attention cannot be given to the milk, because the flavor is one of the most important characteristics of Neufchâtel cheese. The flavor of the cheese can be no better than the flavor of the milk from which it is made. Gassy milk gives the cheese not only a poor flavor, but also a poor body.

Method of manufacture. — The manufacture of Neufchâtel cheese is similar to that of baker's cheese. The milk to be used should be placed in tall cans holding about 30 lb. The temperature of the milk should be brought to 72° F., and the cans should then be placed in a vat or a tank of water of the same temperature. The vat or tank should be filled with cans, so that the cans will not float. If there is a room in which the temperature can be controlled, the cans may be placed in this room and it will not be necessary to set them in water. If the milk is received in the morning and there is danger of a higher development of acidity than 0.2 per cent before setting in the afternoon, the milk should be held cold until it is ready to be set, when it should be warmed.

The milk should be set in the afternoon, and at this time the acidity should be not higher than 0.2 per cent. If the acidity is higher than this, cheese of acid flavor and grainy texture will probably result.

With the milk at a temperature of 72° F., sufficient starter should be added so that on the following morning the whey — from which the curd will have separated — will show 0.35 per cent acidity. To accomplish this will require about 1 c.c. of

commercial starter to 30 lb. of milk. After the starter has been thoroughly mixed with the milk, rennet extract should be added, at the rate of ½ c.c. to 30 lb. of milk. Before adding it to the milk, however, the rennet extract should be diluted in cold water. This should give a firm coagulation, which will draw away slightly from the side of the can, and on the following morning a little free whey will appear on top of the curd. If this whey does not show 0.35 per cent acidity, the dipping must be postponed until this degree of acidity has developed.

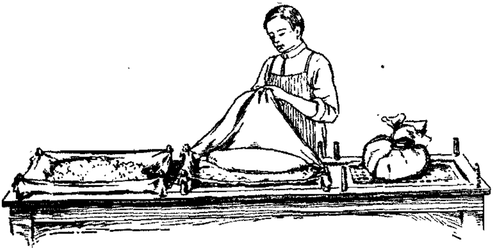


FIG. 83. — Draining table, showing different steps in draining and tying cheese.

The curd should be very carefully dipped with a ladle on to a cloth suspended at the four corners, and allowed to drain. The contents of each can should be dipped on to a separate cloth (Fig. 83), so that the curd may dry evenly. Factory cotton is a good cloth for this purpose, because it is of fine enough weave so that the curd particles will not go through; ordinary cheesecloth cannot be used without a considerable loss of curd particles. The curd should not be broken too fine in dipping, as this prevents the whey from separating rapidly and there will be a greater loss of fat than is necessary. If care is taken not to break the curd, it may be poured out of the cans,

but it is safer for an inexperienced person to dip the curd with a ladle.

After the curd has drained for a few minutes it should be rolled loose from the cloth by carefully pulling up the side of the cloth (see Fig. 83). This separates the dry curd from the cloth and gives the whey an opportunity to escape. This process must be repeated several times, until most of the visible free whey has escaped; the curd may then be wrapped up in the cloth, and pressure gradually applied to force out the whey (see Fig. 84). Too much or too heavy pressure at first will cause a considerable loss of fat, and is likely to force curd particles through the meshes of the cloth. The pressure should be removed every few minutes so that the cloth may be opened and the curd may be stirred. If not stirred, the curd next to the cloth will become very dry, so that it will not mix readily with the softer curd, and this will produce a cheese of lumpy texture.

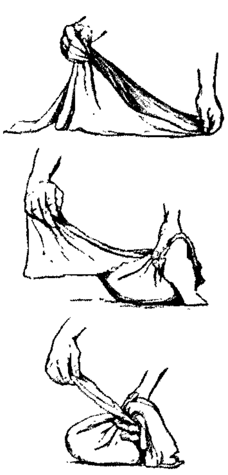


FIG. 84.—Steps in tying the cheese.

When the curd has become dry enough to be put up, salt is evenly mixed through it at the rate of 2 ounces of salt to 10 lb. of curd. The question of when the curd is sufficiently dry must be left entirely to the judgment of the maker, because there is no quick method of determining the amount of moisture in curd. After the salt has dissolved, the cheeses are molded

into cylindrical forms, one and three-fourths by two and three-fourths inches in size (Fig. 85), and wrapped in tin foil lined with parchment cut five by seven inches. A mold of this size makes a cheese weighing about one-fourth pound. The cheeses are then packed in wooden boxes, twenty-five cheeses in a box.

FIG. 85. — Neufchâtel cheese-mold.

Yield. — The yield of Neufchâtel cheese will vary between wide limits, according to the amount of fat in the milk from which the cheese is made, the amount of moisture left in the curd, and whether or not the milk has been pasteurized.

COMPOSITION OF NEUFCHÂTEL CHEESE

	I	II	III	IV	V	AVERAGE
Water	55.6	60.3	62.3	58.1	62.6	59.78
Fat	23.0	16.5	17.5	17.0	16.5	18.10
Protein	16.5	17.6	15.3	20.0	15.5	16.98
Acid (calculated as lactic acid)	1.9	2.0	2.0	2.1	1.8	1.96
Milk-sugar	1.6	1.6	1.5	1.4	1.6	1.54
Ash	1.4	2.0	1.4	1.4	2.0	1.64

Qualities of Neufchâtel cheese. — Neufchâtel cheese should have a distinct, mild, clean flavor, resembling the odor of freshly drawn milk. The texture should be fairly dry and smooth, with no hard, dry lumps nor grains. There should be no whey leaking from the cheese. Neufchâtel curd forms the basis of a number of other varieties of cheese, made by mixing nuts, pimento, cream, and other substances with the curd.

Cream cheese.

Cream cheese can be made in either one of two ways — by [illegible] cream with Neufchâtel curd or by a method very

similar to that used in making Neufchâtel cheese except that cream testing 10 per cent fat is used instead of milk.

Method of manufacture using Neufchâtel curd. — When cream is mixed with Neufchâtel curd, it is difficult to get cheese as rich as that obtained by making the curd from cream testing 10 per cent fat, because if too much cream is added to the Neufchâtel curd it will become so moist, and usually so sticky, that it cannot be handled. One lb. of heavy cream testing about 50 per cent fat, mixed with 5 lb. of Neufchâtel curd, will ordinarily give a good grade of cream cheese. Care should be taken not to mix the curd so much that it will become salvy. Usually it will be necessary to add a little more salt to the cheese. This method is much quicker and is less wasteful than making the cheese from cream testing 10 per cent fat.

Method of manufacture using 10 per cent cream. — When cream testing 10 per cent fat is to be used in making cheese, the method is very similar to that for making Neufchâtel cheese. The cream is placed in 30-pound cans and brought to a temperature of 72° F., in the same way as for Neufchâtel cheese, and the same degree of acidity is developed at the time of dipping. A greater quantity of rennet extract is used, this usually being about 1 c.c. to 30 lb. of milk. This gives a quicker coagulation, thus preventing a loss of fat which would occur if the cream were allowed to rise before coagulation took place. The following morning the curd is dipped on to a cloth, and from this point on the method is the same as that used for Neufchâtel. With this method there is a considerable loss of fat, which is pressed out with the whey. For this reason the method is not extensively used.

Yield. — The yield of cream cheese is a little more than that of Neufchâtel cheese, due to the extra fat. The average yield is from 22 to 24 lb. of cheese from 100 lb. of 10 per cent cream, or from the curd from 100 lb. of milk made by the Neufchâtel method with cream added.

COMPOSITION OF CREAM CHEESE

	I	II	III	IV	V	AVERAG
Water	57.5	50.8	49.6	52.8	50.8	52.30
Fat	23.4	33.0	33.5	28.0	31.5	29.88
Protein	13.6	11.7	12.4	14.9	13.7	13.26
Acid (calculated as lactic acid)	1.6	1.4	2.1	1.4	1.5	1.60
Milk-sugar	1.8	1.8	1.0	1.7	1.2	1.50
Ash	2.1	1.3	1.4	1.2	1.3	1.45

Marketing. — Cream cheese is always put up in rectangula forms, measuring $1\frac{1}{4}$ by $2\frac{1}{2}$ by $2\frac{3}{4}$ inches. A tin mold used fo pressing cream cheese is show in Fig. 86. The cheeses weig about $\frac{1}{4}$ lb. They are wrappe in tin foil and put in boxes twelve cheeses in a box.

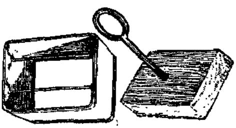


FIG. 86. — Mold for cream cheese.

Qualities of cream cheese. — Cream cheese should have a clean, mild, acid flavor, re sembling well-ripened cream. It should be of a creamy con sistency, but not salvy. It should not be grainy in texture and there should be no hard, dry lumps.

Pimento cheese.

Pimento cheese, which is much used for sandwiches, is mad by adding pimentos to Neufchâtel curd. A pound of pimento is sufficient for from 8 to 10 lb. of curd.

Method of manufacture. — The pimentos are chopped ver fine; this is best done by running them through a food chopper They are then put into the curd and thoroughly mixed througl it. A small pinch of red pepper should be added, to give th cheese a pungent taste. The mixing can be more satisfactoril and evenly done if the pimentos are partly mixed with th

cheese and then the whole mass is run through the food chopper. In order to do this and to be sure that the texture will not be salvy, the curd should be cold.

A better color can be obtained if cheese color is added to the milk from which the cheese is made, at the rate of 1 c.c. of color to 30 lb. of milk. The color, which may be diluted with water or milk, should be added after the starter is added but before the rennet extract is put in.

Yield. — The yield of pimento cheese will be a little more than that of Neufchâtel cheese, due to the added pimento; but there will be some loss of curd due to grinding.

Marketing. — Pimento cheese may be molded in either the Neufchâtel or the cream cheese mold, and then wrapped in parchment or tin foil. Put up in this way, however, it does not keep very long. Many manufacturers are now putting the cheese into glass jars with screw tops, which hold from 3 to 4 ounces. In such a package the cheese will keep much longer, and the original package may be placed directly on the consumer's table and used as long as the cheese lasts. The glass jars are a little more expensive than the tin foil or the parchment paper, but the added expense is made up by the longer commercial life of the cheese.

Qualities of pimento cheese. — Pimento cheese should have a distinct but clean pimento flavor, with a biting taste. It should have a soft, but not salvy, texture, so that it can be evenly spread on bread and crackers. There should be no free whey dripping from the cheese.

Club cheese.

Club cheese is known by a variety of names and is manufactured by many different methods. It is made largely from cheddar cheese, so that it is especially liked by persons who like the cheddar flavor or a strong cheese flavor. It has a soft texture so that it spreads easily, and is therefore much used for sandwiches.

Method of manufacture. — As stated already, there are many different methods of making club cheese, one method being as follows:

Well ripened or old cheddar cheese is ground in a food chopper and butter is mixed with it. The older the cheddar cheese, the stronger will be the flavor of the club cheese. Cheese and butter of good flavor should be used. The amount of butter to be used will depend on the amount of moisture in the cheese and the length of time the cheese is to be kept. If the cheese is dry, more butter should be put in, in order to make the texture soft; but if the cheese is to be kept for a long time, too much butter is likely to make it become rancid. Usually 1 lb. of butter to 8 or 10 lb. of cheese is sufficient.

In order to do away with all lumps in the texture, it is sometimes necessary to run the mixed cheese and butter through the food chopper a second time. While all lumps must be worked out of the cheese, care should be taken not to work the cheese so much that it will become salvy and sticky.

Usually a little pepper is added, to give the cheese a biting taste. Some manufacturers add a great variety of substances, but these are not necessary and destroy the flavor of the cheese.

Marketing. — Club cheese may be wrapped in tin foil or put up in air-tight glass jars. The latter practice, while more expensive, has the advantage of making the cheese keep longer; but for local trade tin foil is just as satisfactory as glass. In filling the glass care must be taken not to leave any air spaces between the cheese and the glass, as this is likely to cause the cheese to mold. A glass jar can be filled and air spaces prevented by first smearing a very thin layer of cheese over the glass.

Summary.

1. There is nothing in connection with the manufacture of soft cheeses which after a few trials the average cheese-maker cannot master.

2. In order to have the best cheese possible there must be a supply of good milk.

3. A good starter must be used in connection with the cheese.

4. Soft cheeses can often be made and marketed in connection with butter-making on the farm.

5. The commercial life of soft cheeses is so short that there must be an easily available and ready market.

6. While there is a large profit in the making of soft cheeses, there are so many losses that in many cases what appears to be a profit will be turned to a loss before the cheese can be sold.

PROBLEMS IN DAIRY ARITHMETIC

The dairyman needs to make many mathematical calculations in connection with the handling of his products. As a guide in solving the more common problems, the following examples and directions are given.

Market milk and cream (Ross)

Converting pounds to quarts and quarts to pounds.

In converting quarts of milk to pounds or pounds to quarts, it is necessary to know that a quart of milk weighs 2.15 lb. While it is true that the composition of milk is variable, the difference in weight is not great enough to affect the practicability of always using 2.15 lb. as the weight of one quart of whole milk.

The weight of a quart of cream is not constant because the percentage of fat in cream is exceedingly variable. The following table gives the weight of a quart of cream of different percentages of fat:

Percentage of Fat	Weight of One Quart of Cream in Pounds	Weight of One Gallon of Cream in Pounds
20	2.115	8.460
25	2.100	8.400
30	2.088	8.352
40	2.055	8.220
50	2.028	8.112

Problem 1

40 quarts of milk is equal to how many pounds?
1 qt. of milk weighs 2.15 lb.
40 qt. weigh 2.15 lb. × 40 = 86 lb. *Answer.*

Problem 2

79.55 lb. of milk equals how many quarts?
2.15 lb. of milk equals 1 qt.
In 79.55 lb. there would be 79.55 ÷ 2.15 = 37, number of quarts. *Answer.*

In the same way, by referring to the table given and finding the weight of a quart of cream of a certain percentage of fat, quarts of cream may be converted to pounds and pounds to quarts.

Problem 3

What would be the weight of 20 gallons of 30 per cent cream?
One gallon of 30% cream weighs 8.352 lb.
20 gal. weigh 8.352 lb. × 20 = 167.04 lb. *Answer.*

Computing the pounds of fat in dairy products.

In order to find the number of pounds of fat in dairy products it is necessary to know the number of pounds of the product and its percentage of fat.

Problem 4

Compute the pounds of fat in the following:

A	Whole milk	82 lb., testing 3.8 per cent fat
B	Cream	80 lb., testing 39 per cent fat
C	Cream	80 lb., testing 40 per cent fat
D	Cream	83 lb., testing 20 per cent fat
E	Buttermilk	85 lb., testing .12 of 1 per cent fat
F	Skimmed milk	84 lb., testing .03 of 1 per cent fat
G	Whey	85 lb., testing .32 of 1 per cent fat

Answers

A	82 × .038	= 3.116, number of pounds of fat
B	80 × .39	= 31.2, number of pounds of fat
C	80 × .40	= 32.0, number of pounds of fat
D	83 × .20	= 16.6, number of pounds of fat
E	85 × .0012	= .102, number of pounds of fat
F	84 × .0003	= .0252, number of pounds of fat
G	85 × .0032	= .272, number of pounds of fat

Computing percentage of fat, pounds of product, or pounds of fat, having any two of these quantities given.

PROBLEM 5

How many pounds of milk testing 4.5 per cent fat would be required to furnish 157.5 lb. of fat?

? lb. milk × .045 = 157.5

Therefore, 157.5 ÷ .045 = 3500, number of pounds of 4.5% milk. *Answer.*

PROBLEM 6

250 lb. of cream contained 75 lb. of fat. What did the cream test?

250 × ? = 75 lb. fat

Therefore, 75 ÷ 250 = .30

.30 × 100 = 30%, fat test. *Answer.*

PROBLEM 7

How many pounds of 22 per cent cream can be obtained from 3500 lb. of 4 per cent milk?

In 3500 lb. of 4% milk there are 140 lb. of fat (3500 × .04 = 140).

This amount of fat will be contained in the 22% cream. The problem is to find the number of pounds of cream testing 22%.

? lb. cream × .22 = 140

Therefore, 140 ÷ .22 = 636.36, number of pounds of cream. *Answer.*

Standardizing milk and cream.

Standardizing milk or cream consists in raising or lowering the fat-content to a fixed standard. This is done by adding to the material to be standardized, milk or cream of a higher or lower percentage of fat. In standardization there are two classes of problems involved: first, one in which a certain fixed amount of milk is to be made up or a certain amount of standardized milk is desired; and second, one in which a certain amount of milk or cream is to be used and enough of another product added to make the mixture test a certain percentage of fat. In the latter case the amount of the mixture is indefinite.

The original method of computing problems in standardization is long and difficult, but a scheme has been devised that is comparatively simple.[1] The method is as follows:

Draw a rectangle and place in the center of it the percentage of fat

[1] By R. A. Pearson, at that time Professor of Dairy Industry, Cornell University.

desired. Place at the left-hand corners of the rectangle the percentages of fat in the materials to be mixed. Subtract the number in the center from the larger number at the left of the rectangle. Place the remainder on the diagonally opposite right-hand corner of the rectangle. Subtract the smaller number on the left-hand corner from the number in the center and place the remainder on the diagonally opposite right-hand corner of the rectangle.

The two numbers on the right-hand corners of the rectangle represent the number of pounds of material required. If these two numbers are added they will express the number of pounds of the mixture, which will contain a percentage of fat expressed by the number in the center of the rectangle. In each case the number on the right-hand corner corresponds in fat test to the number on the left-hand corner directly opposite.

Problem 8

How many pounds of 40 per cent cream and 3 per cent milk must be mixed to make milk testing 5 per cent? Using the diagram as described, the following result is obtained:

This means that if 2 lb. of 40% cream are mixed with 35 lb. of 3% milk, the result will be a 37-lb. mixture testing 5%. *Answer.*

Problem 9

How many pounds of 28 per cent cream and 3 per cent milk will be required to make 500 lb. of a mixture testing 4 per cent? In this problem a definite number of pounds of the mixture is required. According to the conditions of the problem there would be 500 lb. of 4% milk. This amount of milk would contain 20 lb. of fat ($500 \times .04 = 20$). According to the results the 500 lb. would be made up of 480 lb. of 3% milk and 20 lb. of 28% cream. The 480 lb. of 3% milk would contain 14.4 lb. of fat ($480 \times .03 = 14.4$). The 20 lb. of 28% cream would contain 5.6 lb. of fat ($20 \times .28 = 5.6$).

$14.4 + 5.6 = 20$

Since the 500 lb. contain 20 lb. of fat, and the materials of which the 500 lb. is made up furnish the 20 lb. of fat, the problem is worked correctly.

Problem 10

How many pounds of 3 per cent milk must be mixed with 150 lb. of 28 per cent cream to make a mixture testing 4 per cent? In this problem the number of pounds to be made up is not definitely known. Working the problem by the rectangle method, 1 part of 28% cream is required for 24 parts of 3% milk. According to the terms of the problem, 150 lb. of 28% cream must be used, and this is 150 times as

large as in the above proportion. The 28% cream and 3% milk must be kept in the proportion of 1 : 24, and since the amount of 28% cream is to be increased 150 times, the 3% milk must also be increased 150 times. This would give 150 lb. of 28% cream (1 × 150) and 3600 lb. of 3% milk (150 × 24 = 3600), making in all 3750 lb. (150 + 3600 = 3750) of a 4% mixture.

This problem may also be worked by simple proportion:

$24 : 1 :: x : 150$

$x = 3600$, the number of pounds of 3% milk required.

PROOF

The 3750 lb. of 4% milk will contain 150 lb. of fat (3750 × .04 = 150).

If the 150 lb. of 28% cream and 3600 lb. of 3% milk furnish 150 lb. of fat, the problem is correct.

3600 × .03 = 108, number of pounds of fat in milk
150 × .28 = 42, number of pounds of fat in cream
108 + 42 = 150, number of pounds of fat in mixture. *Answer.*

Computing the average percentage of fat in the milk of a herd.

PROBLEM 11

Compute the average test of fat of this herd:

Brownie	20 lb. milk testing 4.2 per cent fat	
Spot	50 lb. milk testing 3 per cent fat	
Red	20 lb. milk testing 4.5 per cent fat	
Nancy	10 lb. milk testing 5 per cent fat	
Lucy	40 lb. milk testing 3.5 per cent fat	

This problem is solved as follows:

Brownie	20 × .042	= .84,	number of pounds fat
Spot	50 × .03	= 1.50,	number of pounds fat
Red	20 × .045	= .90,	number of pounds fat
Nancy	10 × .05	= .50,	number of pounds fat
Lucy	40 × .035	= 1.40,	number of pounds fat
	140	5.14	

5.14 (lb. fat) ÷ 140 (lb. milk) = .0367
.0367 × 100 = 3.67%, fat test. *Answer.*

The common *incorrect* method of solving this problem is as follows:

4.2% + 3.0% + 4.5% + 5.0% + 3.5% = 20.2%, sum of tests
20.2% ÷ 5 (number of tests) = 4.04%, *incorrect average.*

Had all the cows given the same amount of milk, the latter method would have given the correct answer.

Computing fat recovered during separation.

PROBLEM 12

A farmer separating 200 lb. of milk testing 5 per cent fat loses some fat in the skimmed milk, some milk or cream is spilled, and a little adheres to the utensils. He gets 30 lb. of cream testing 33 per cent fat. What percentage of the fat in the whole milk does he recover in the cream?

$200 \times .05 = 10$, number of pounds of fat in milk

$30 \times .33 = 9.9$, number of pounds of fat in cream

$9.9 \div 10 = .99$

$.99 \times 100 = 99$, percentage of fat of the whole milk recovered in the cream. *Answer.*

Comparative value of different methods for disposing of milk and its products.

Many dairymen lose money when selling cream, by not charging a price in proportion to the price obtained for milk. In computing a relative price for milk and cream it is best to reduce each to a fat-percentage basis.

PROBLEM 13

Milk dealer X sells milk testing 4 per cent fat at 8 cents a quart. For how much a quart should he sell cream testing 32 per cent fat in order to receive a price for the cream that is relative in amount to the price received for the milk?

Milk dealer Y sells milk testing 3.5 per cent fat at 8 cents a quart. How much should he receive a quart for cream testing 29 per cent fat, in order that the price of the cream will be relative to that of the milk?

(X) 100 lb. of 32% cream will contain 32 lb. of fat ($100 \times .32 = 32$)
100 lb. of 4% milk will contain 4 lb. of fat ($100 \times .04 = 4$)

Therefore, a given quantity of cream will contain 8 times as much fat as the same quantity of milk ($32 \div 4 = 8$). The cream should therefore be worth 8 times as much as the milk. Since the milk sold for 8 cents a quart, the cream should sell for 8 cents $\times$ 8, or 64 cents. *Answer.*

(Y) 100 lb. of 29% cream will contain 29 lb. of fat ($100 \times .29 = 29$)
100 lb. of 3.5% milk will contain 3.5 lb. of fat ($100 \times .035 = 3.5$)

$29 \div 3.5 = 8.28$

The cream should be worth 8.28 times as much as the milk, or 8 cents $\times$ 8.28, which is 66 cents. *Answer.*

PROBLEM 14

Which of the following is the most profitable method of disposing of milk testing 4 per cent fat: (*a*) at $3\frac{1}{2}$ cents a quart; (*b*) to a cheese factory at $1.20 for 100 pounds (considering that 85 per cent of milk is whey, which is returned and is valued at 15 cents for 100 pounds); (*c*) cream testing 21 per cent fat to a special trade at 18 cents a quart; (*d*) cream testing 40 per cent fat to a creamery at 27 cents a pound for the fat; (*e*) to make butter on the farm and sell it for 30 cents a pound and the buttermilk for 10 cents a gallon, overrun 12 per cent?

In all cases consider the skimmed-milk to be worth 18 cents per 100 pounds.

It must be noted that no allowance is made for waste or for cost of handling.

(*a*) 100 (lb. milk) ÷ 2.15 (lb. per qt.) = 46.5, number of quarts in 100 lb. milk

$.03½ × 46.5 = $1.62. *Answer.*

(*b*) 100 × .85 = 85, number of pounds whey in 100 lb. milk

15 cents × .85 = 12 cents, value of whey

$1.20 (value of milk) + $.12 (value of whey) = $1.32. *Answer.*

(*c*) 100 × .04 = 4, number of pounds fat in 100 lb. milk

4 (lb. fat) ÷ .21 (test of cream) = 19.04, number of pounds cream

19.04 ÷ 2.115 = 9, number of quarts cream

18 cents × 9 = $1.62

100 (lb. milk) − 19.04 (lb. cream) = 80.96, number of pounds skimmed-milk

$.18 (value of skimmed-milk per cwt.) × .8096 = $.14

$1.62 (value of cream) + $.14 (value of skimmed-milk) = $1.76. *Answer.*

(*d*) 100 × .04 = 4, number of pounds fat in 100 lb. milk

$.27 × 4 = $1.08, value of fat

4 (lb. fat) ÷ .40 (test of cream) = 10, number of pounds cream

100 (lb. milk) − 10 (lb. cream) = 90, number of pounds skimmed-milk

$ .18 (value of skimmed-milk per cwt.) × .90 = $.16

$1.08 (value of cream) + $.16 (value of skimmed-milk) = $1.24. *Answer.*

(*e*) 100 × .04 = 4, number of pounds fat in 100 lb. milk

4 (lb. fat) ÷ .30 (test of cream) = 13.33, number of pounds cream

4 (lb. fat) × .12 (overrun) = .48, number of pounds overrun

4 + .48 = 4.48 lb. butter

13.33 (lb. cream) − 4.48 (lb. butter) = 8.85, number of pounds buttermilk

1 gal. buttermilk = 8.7 lb.

Therefore, 8.85 lb. buttermilk = approximately 1 gal.
\$.10 × 1 = \$ .10, value of buttermilk
\$.30 × 4.48 (lb. butter) = \$1.34, value of butter
100 (lb. milk) − 13.33 (lb. cream) = 86.67, number of pounds skimmed-milk
\$.18 (value of skimmed-milk per cwt.) × 86.67 = \$.15
\$.10 (value of buttermilk) + \$1.34 (value of butter) + \$.15 (value of skimmed-milk) = \$1.59. *Answer.*

BUTTER PROBLEMS (Guthrie)

Computing overrun in butter.

Overrun is the increase in the amount of butter made from a given amount of fat, or it is the sum of the moisture, the salt, and the casein of the butter minus the losses in manufacture.

PROBLEM 15

(*a*) Butter-maker X has 1000 lb. of cream testing 35 per cent fat. From it he makes 400 lb. of butter. Compute the percentage of overrun and the value of the overrun at 25 cents a pound.

1000 × .35 = 350, number of pounds fat
400 (lb. butter) − 350 (lb. fat) = 50, weight in pounds of overrun
50 ÷ 350 = .142
.142 × 100 = 14.2%, overrun. *Answer.*
\$.25 × 50 = \$12.50, value of overrun. *Answer.*

(*b*) Butter-maker Y is more careful in preventing leaks and wastes, and he understands butter-making better than does X. From 1000 lb. of cream testing 35 per cent fat he makes 420 lb. of butter. Compute the percentage of overrun and its value at 25 cents a pound.

1000 × .35 = 350, number of pounds fat
420 (lb. butter) − 350 (lb. fat) = 70, weight in pounds of overrun
70 ÷ 350 = .20
.20 × 100 = 20%, overrun. *Answer.*
\$.25 × 70 = \$17.50, value of overrun. *Answer.*

Butter-maker Y has made from the same amount of fat \$5 worth more butter than has X.

PROBLEM 16

Mr. Smith has a herd of ten cows, from each of which he receives yearly 250 lb. of fat that he makes into butter. His average overrun was 12 per cent until he bought apparatus for making a moisture test and began to prevent some of his losses. His average overrun is now

15 per cent. With the price of butter at 25 cents a pound, how much greater are his receipts a year now than formerly?

250 lb. (fat per cow) × 10 = 2500 lb., fat for the herd
2500 × .12 = 300, number of pounds overrun at 12%
2500 (lb. fat) + 300 (lb. overrun) = 2800, number of pounds butter
$.25 × 2800 = $700, value of butter with 12% overrun
2500 × .15 = 375, number of pounds overrun at 15%
2500 (lb. fat) + 375 (lb. overrun) = 2875, number of pounds butter
$.25 × 2875 = $718.75, value of butter with 15% overrun
$718.75 = $700.00 = $18.75 increase in receipts. *Answer.*

A shorter method of solution:

15% overrun − 12% overrun = 3%, increase in overrun
2500 × .03 = 75, number of pounds increase in overrun
$.25 × 75 = $18.75, increase in receipts. *Answer.*

Butter yield of cream.

PROBLEM 17

How much cream testing 30 per cent will it be necessary to churn in order to produce 360 lb. of butter, overrun on fat 20 per cent?

Since there is an overrun of 20%, a certain number of pounds of fat must have been multiplied by 1.20 in order to produce 360 lb. of butter.

? lb. of fat × 1.20 = 360
Therefore, 360 ÷ 1.20 = 300, number of pounds of fat

It now remains to find the number of pounds of 30% cream from which the fat was taken.

? lb. cream × .30 = 300
Therefore, 300 ÷ .30 = 1000, number of pounds of 30% cream. *Answer.*

CHAPTER XII

CONDENSED AND POWDERED MILK

FLUID milk is bulky and expensive to transport, and under normal conditions its life for direct consumption is not more than two or three days. These factors very greatly limit its use as human food. It is chiefly for the purpose of overcoming these difficulties that milk is condensed or made into milk flour. The removal of a large percentage of the water greatly reduces the cost of transportation per unit of value, and the concentration of the solids; the addition of sugar or the sterilization of the finished product increases its keeping quality to several weeks or even months. This makes it possible to use these milk products under conditions which would make the use of fluid milk impossible.

The condensed-milk industry in America began with the invention of Gail Borden, who "found[1] a way of extracting seventy-five per cent of the water, and then added a quantity of pure granulated sugar to the residue, which preserved its sweetness, and the result was the 'condensed milk' known by the inventor's name through the world. Although he made application for a patent in 1853, it was three years before it was granted, his claim that the method of 'evaporation by means of a certain vacuum' was the important point of the discovery, being disputed by the patent office." Mr. Borden was finally able to convince the patent office of the usefulness of his invention and a patent was granted August 19, 1856.

[1] National Cyclopædia of American Biography.

During the same year his first plant for the production of condensed milk was erected at Wolcottville, Connecticut. At first, this product did not prove popular, and not until the opening of the Civil War in 1861, when it showed its value as a concentrated food for the army, was the business firmly established. For many years the industry grew slowly, but as the methods of manufacture were perfected the demand for the finished product increased rapidly, until to-day it constitutes a very important branch of the dairy industry.

EXTENT OF THE INDUSTRY

The United States Census states that in 1904 there were eighty-one condensed milk factories in the United States; in 1909, one hundred thirty-six; while in 1914, there were one hundred and ninety. During the decade 1899–1909, the production of condensed milk increased 307,874,757 pounds, or 164.7 per cent. In 1909, condensed milk was produced in only a few states. The combined output of the three states of New York, Illinois, and Washington represented 58.4 per cent of the total amount manufactured, while the product of eight states represented 88.4 per cent of the total production. The rapid increase in the production of condensed milk during the ten years from 1899–1909 is shown in the following table both in actual amounts made and also in relation to the production of butter and cheese.

CONDENSED MILK, BUTTER, AND CHEESE MADE IN THE UNITED STATES

UNITED STATES	CONDENSED MILK	BUTTER	CHEESE
	Quantity (pounds)	Quantity (pounds)	Quantity (pounds)
1909	494,796,544	624,764,653	311,126,317
1904	308,485,182	531,478,141	317,144,872
1899	186,921,787	420,126,546	281,972,324

In the earlier years of the industry, most of the condensed milk was the sweetened product because the addition of the sugar increased the keeping quality of the finished product. But since satisfactory methods for sterilizing the unsweetened milk have been developed, the latter has increased in favor and its production has grown much more rapidly than that of the sweetened form. This is shown in the following table, taken from the Census Report.

CONDENSED MILK — QUANTITY AND VALUE OF PRODUCT: 1909, 1904, AND 1899

PRODUCT	1909	1904	1899
Condensed milk:			
Pounds	494,796,544	308,485,182	186,921,787
Value	$33,563,129	$20,149,282	$11,888,792
Sweetened —			
Pounds	214,518,310	198,355,189	(1)
Value	$17,345,278	$13,478,376	(1)
Unsweetened —			
Pounds	280,278,234	110,129,993	(1)
Value	$16,217,851	$6,670,906	(1)

The amounts and value of the condensed milk made in the year 1914 are shown in the table on page 455. In that year the sweetened product was made in seventeen states, the unsweetened in twenty, and the evaporated in nineteen. These figures show the very rapid development and spread of this branch of dairy manufactures in the dairy sections of this country. Since 1914 there has been enormous growth in this industry as the result of greatly increased export trade.

[1] Figures cannot be given without disclosing business of individual concerns.

Condensed Milk Made in the United States in 1914
(Census Report)

	Sweetened		Unsweetened		Evaporated	
	Pounds	Value	Pounds	Value	Pounds	Value
Ill.	58,857,984	$4,937,077	51,823,055	$3,052,538	56,744,055	$3,266,832
Mich.	37,057,100	2,930,006	25,272,035	1,327,576	14,185,520	943,058
New York	72,487,665	6,628,171	37,451,467	2,423,370	21,635,501	1,549,372
Ohio	3,436,823	199,962	24,682,815	1,258,044	22,390,210	1,608,625
Oregon			23,157,414	1,392,698		
Penn.	16,412,103	1,196,528	45,770,344	2,760,541	7,526,470	479,212
Wis.	62,798,619	4,446,798	24,812,784	1,479,486	62,071,127	3,924,238
All other States	16,819,661	1,246,597	98,923,000	6,233,761	89,004,752	5,462,762
Total, U. S.	267,869,955	21,585,139	331,892,914	19,928,014	273,647,635	17,234,099

Grand total for U. S.: Pounds, 873,410,504. Value, $58,747,252.

CONDITIONS ESSENTIAL FOR A MILK CONDENSERY (U. S. Dept. Agr.[1])

First. The plant should be located in a community which is not only thoroughly adapted in every way to a high standard of extensive dairy farming but is already far advanced in such development. The herds of cows should be large, healthy, well cared for, and of a breed or breeds that produce a grade of milk reasonably adapted for condensing purposes and the production of a standard product.

Second. In establishing a plant for condensing milk by the vacuum process it is of primary importance that the location provide an abundant, steady supply of pure, cold water, independent of the supply required for boiler use. The quantity of water required to condense a given quantity of milk will, of course, vary with the operating conditions, such, for example, as the temperature of the condensing water and the temperature (or the pressure) of the vapor to be condensed. A general idea of the importance of water supply can be obtained from the

[1] Weekly News Letter, Vol. II, No. 45.

authoritative estimate that about 3 gallons of water are required for the condensing of 1 pound of fresh milk (about 1 pint). Difficulty in obtaining an adequate supply of good, pure, cold water is a cause of serious embarrassment to some of the commercial condenseries now established, and the lack of it has been the cause of many failures.

Third. An abundant supply of pure milk is an absolute necessity. The exact quantity required daily will, of course, vary with the size of the plant. Several reliable authorities have estimated that for the profitable production of condensed milk on a commercial scale the supply of raw milk to the factory should not fall below 15,000 pounds a day. This estimate is exclusive of the daily supply of milk normally required for other purposes by the community. Furthermore, if the finished product is to be of marketable quality, the milk received at the condensery must be of exceptionally high grade; that is, clean and pure.

While first-class milk is essential for the manufacture of a first-class dairy product of any kind, it is absolutely necessary if a condensed-milk factory is to be a success. If a few cans of low-grade milk are not detected at the receiving platform of a condensery, the slight defects in the raw milk are multiplied in the process of condensing it, and the result is practically certain to be the complete loss of the whole batch, which may represent a financial loss of several hundred dollars. This statement may be illustrated concretely: It is claimed by authorities that raw milk containing as much as 0.2 per cent acid (calculated as lactic acid) is not fit for condensing purposes. This does not necessarily mean that it would taste sour, but if accepted and condensed in the ratio of 2.25 to 1 (it may be more but is seldom less), the acidity, increasing in the same ratio, would reach 0.45 per cent, which would be practically certain to cause a sour taste in the finished product. Every housewife knows that sour

temperature the more rapid is the curdling process and the firmer the curd. This makes it unfit for cooking purposes. In the commercial production of evaporated milk, the product must be sterilized in the cans at a very high temperature in order to insure a good keeping quality. It is obvious, therefore, that if milk is delivered to the factory with a slight excess of acidity it would probably be impossible to sterilize the product obtained from it without producing a hard curd, which would make the product absolutely unsalable, and thus a total loss to the manufacturer. Furthermore, excessive acidity, which is principally caused by improper care and handling of the milk, is not the only condition that may render milk unfit for condensing. Other undesirable qualities of the milk may also be induced by poor health and improper care of the cows, by the kind and the condition of their feed, and by many other details of imperfect management of the dairy farms.

The services of experts thoroughly qualified by training and long experience in this particular line will be required to detect and guard against these unfavorable conditions.

Fourth. Adequate facilities for marketing constitute another essential to the commercial success of a condensed-milk plant. Commercial success, of course, implies a profitable market for the product — a market which is readily and directly accessible to the plant without adding excessively to the cost of manufacture, either in the form of high freight rates or long hauls from the condensery to a railroad. As already indicated, the successful manufacture of condensed milk on a commercial scale requires a large output of the finished product — a very much larger output than is likely to be consumed in the local market; therefore, in selecting a location, favorable transportation facilities to a good market or markets are a consideration of vital importance to ultimate success.

Fifth. In establishing and operating a condensery the necessity of adequate capital is another important question. The

cost of buildings and equipment will, of course, vary with the purchase of superior or inferior materials and workmanship, as well as size of the plant, and, in some measure, the kind of condensed milk to be produced. In any case, however, the buildings should be thoroughly substantial, more so than is commonly considered necessary for a creamery or a cheese factory. The major part of the equipment is of a very highly specialized, more or less complicated, and very expensive type. The proper operation of the equipment, especially the vacuum pan, and the sterilizer when the product is sterilized in cans, calls for a high degree of skill and large experience if serious losses are to be avoided and a standardized legal product is to be produced.

The cost of buildings, equipment, and operation of a plant for the manufacture of evaporated milk (unsweetened condensed milk for household use) will illustrate the capital required for the manufacture of any other form of condensed milk. Some reliable authorities have conservatively estimated that adequate buildings and equipment for a minimum production on a commercial scale would cost in the neighborhood of $25,000, exclusive of working capital. The markets for condensed milk at best are very unstable. Frequently the manufactured product must be held several months before it is marketed. In the meantime the plant must be kept in operation, for which a very considerable surplus capital must be provided. The same authorities estimate this item at $10,000.

It therefore appears that in establishing and operating a milk condensery capital to the amount of at least $35,000 must be provided. That this estimate is conservative is indicated by the fact that manufacturers of condensed milk have stated that a capital of $50,000 is usually necessary to operate a condensed-milk factory.

Sixth. Commercial success in any manufacturing enterprise usually requires much more than merely placing the product upon the market. A demand for the product must be firmly

established and a regular trade developed before success is assured. To attain such a result the new product must meet the keen competition of similar products already well established. There are many well-established brands of condensed milk now on the market. There may be room for many more, but new brands, regardless of their quality, must expect to overcome strong competition before a firm foothold is gained. This usually requires extensive advertising and a competent, vigorous sales force, which entails a heavy expense. Good salesmanship and advertising must be continued. The necessity of a thoroughly organized selling organization should, therefore, not be overlooked.

DEFINITIONS AND STANDARDS

The following definition and standard for condensed milk, evaporated milk, and concentrated milk was adopted by the Joint Committee on Definitions and Standards of the American Association of Dairy, Food, and Drug Officials, the Association of Official Agricultural Chemists, and the United States Department of Agriculture, on November 20, 1914:

"*Condensed milk, evaporated milk, concentrated milk,* is the product resulting from the evaporation of a considerable portion of the water from the whole, fresh, clean, lacteal secretion obtained by the complete milking of one or more healthy cows, properly fed and kept, excluding that obtained within fifteen days before and ten days after calving, and contains, all tolerances being allowed for, not less than twenty-five and five-tenths per cent (25.5%) of total solids and not less than seven and eight-tenths per cent (7.8%) of milk-fat."

Very recently the same Associations and Committees have adopted revised definitions and standards which have not yet been adopted by the United States Department of Agriculture. By the new definitions, condensed milks are classified and defined as follows:

"*Sweetened condensed milk* is the product resulting from the evaporation of a considerable portion of the water from milk to which sugar (sucrose) has been added. It contains, all tolerances being allowed for, not less than twenty-eight per cent (28.0%) of total milk solids, and not less than eight per cent (8.0%) of milk-fat."

"*Sweetened condensed skimmed milk, sweetened evaporated skimmed milk, sweetened concentrated skimmed milk,* is the product resulting from the evaporation of a considerable portion of the water from skimmed milk to which sugar (sucrose) has been added. It contains, all tolerances being allowed for, not less than twenty-eight per cent (28.0%) of milk solids."

"*Condensed skimmed milk, evaporated skimmed milk, concentrated skimmed milk,* is the prodnct resulting from the evaporation of a considerable portion of water from skimmed milk, and contains, all tolerances being allowed for, not less than twenty per cent (20.0%) of milk solids."

PROCESS OF MANUFACTURE FOR UNSWEETENED CONDENSED MILK (Hunziker and Spitzer)[1]

The milk is first heated to temperatures varying in the different factories from 160° F. to the boiling point. The apparatus nsed for heating may be an open copper kettle where live steam is turned into the milk, or it may be a jacketed kettle equipped with a revolving stirrer, the jacket furnishing the heating surface, or a continuous pasteurizer may be used. In most factories live steam is turned direct into the milk.

The bot milk is drawn up into the vacuum pan (see Fig. 87) where it is condensed under reduced pressure (about 25 inches of vacuum) and at a temperature of from 130° F. to 150° F. The length of time it takes for condensing the milk down to the desired consistency varies with the amount of milk in the

[1] **Ind. Bul. 134.**

pan, area of heating surface, capacity of vacuum pump, and amount and temperature of water in the condenser. In some factories the condensed milk is superheated before it leaves the vacuum pan by conducting live steam into it. In others this part of the process is omitted.

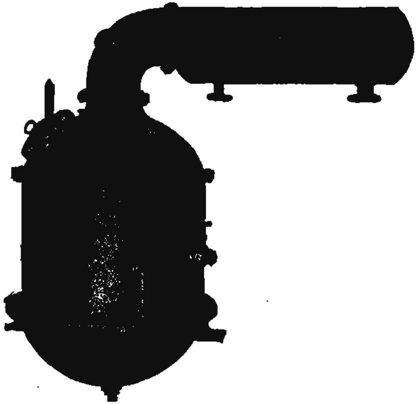


FIG. 87. — Vacuum pan for condensing milk.

The condensed milk with a specific gravity of about 1.06 to 1.09 is then cooled and filled into tin cans; the cans are hermetically sealed and are now ready for the sterilizer.

The sterilizer is a huge cylinder, heavily constructed and carrying in its interior a revolving framework into which the cans are placed and locked. In the sterilizer the cans are heated with steam under pressure to temperatures varying from 226° F. to 240° F. according to the process employed, the condition of

the milk, and the season of the year. The sterilizing process occnpies from one to two hours, varying with the temperature applied and rapidity of heating. Before the cans leave the sterilizer they are cooled sufficiently so they can be handled conveniently.

From the sterilizer the cans pass into the shaker, a machine consisting of one or more heavy iron boxes into which the cans are wedged and which move back and forth on an eccentric, subjecting the cans and their contents to violent shaking, for the purpose of giving the evaporated milk a smooth and homogeneous body.

EFFECT OF CONCENTRATION UPON ACIDITY (Hunziker)[1]

The action of heat on the properties of milk is intensified by the concentration of the milk. The greater the ratio of concentration, the more intense is the action of heat on milk. This fact can be demonstrated mathematically in the ease of the acidity of milk; milk received at the factory may contain, say .17 per cent acid. If the milk is condensed 2 : 1, the condensed milk will contain approximately $.17 \times 2$, or .34, per cent acid. If the ratio of concentration is 2.5 : 1, the condensed milk will contain $.17 \times 2.5$, or .425, per cent acid. This increase in the per cent of acid of the 2.5 : 1 condensed milk is sufficient in most cases to cause the same sterilizing temperature to curdle such milk into a firm and hard curd that cannot be shaken out mechanically.

The actual relation of the per cent of acid to the degree of concentration and its effect on the physical condition of the evaporated milk is clearly shown in the following table. This table shows the results of evaporating fresh milk to different degrees of concentration.

[1] Ind. Bul. 143.

Increase of the Per Cent of Acid as the Concentration of the Evaporated Milk Increases and Its Effect on the Curdling of the Casein

Lot No.	Concentration	Per Cent Acid	Condition of Casein
1	1.58 : 1	.30	Not precipitated
2	1.74 : 1	.34	Not precipitated
3	1.9 : 1	.40	Not precipitated
4	1.99 : 1	.43	Not precipitated
5	2.11 : 1	.48	Small lumps of curd
6	2.25 : 1	.54	Large lumps of curd

The different lots of evaporated milk were made from the same batch of fresh milk. The fresh milk tested .17 per cent lactic acid. Evaporated milk with a concentration of 1.58 parts of fresh milk to 1 part of evaporated milk contained .30 per cent acid. There was a continuous rise in the per cent of acid, the more concentrated the product. Evaporated milk condensed at the ratio of 2.25 : 1 contained .54 per cent acid.

The degree of concentration is also an important factor in determining the marketable properties of the finished product. This is shown by the results of work done by Hunziker,[1] who conducted experiments at different times during the season. The results of these experiments are given in three tables which follow:

June Experiment

No.	Concentration	Milk Solids	Condition of Sample One Month after Manufacture
		per cent	
1	1.61 : 1	20.40	Fat separated and churned, no curd
2	1.96 : 1	24.87	Smooth, no separation, no curd
3	2.00 : 1	25.38	Smooth, no separation, no curd
4	2.20 : 1	28.02	Curdy, lumps of curd, fat not separated
5	2.52 : 1	31.99	Curdy, lumps of curd, fat not separated

Total solids in fresh milk, 12.68 per cent.
Acidity in fresh milk, .16 per cent.

AUGUST EXPERIMENT

No.	Concentration	Milk Solids	Condition of Sample One Month after Manufacture
		per cent	
1	1.94 : 1	22.79	Fat separated and churned, no curd
2	2.11 : 1	24.81	Fat separated and churned, no curd
3	2.21 : 1	26.01	Smooth, no separation, no curd
4	2.33 : 1	27.33	Curdy, small lumps of curd, no separation
5	2.5 : 1	29.37	Curdy, lumps of curd, no separation

Total solids in fresh milk, 11.75 per cent.
Acidity in fresh milk, .12 per cent.

NOVEMBER EXPERIMENT

No.	Concentration	Milk Solids	Condition of Sample One Month after Manufacture
		per cent	
1	1.58 : 1	21.12	Fat separated and churned, no curd
2	1.74 : 1	23.25	Fat separated and churned, no curd
3	1.9 : 1	25.48	Smooth, no separation, no curd
4	1.99 : 1	26.62	Smooth, no separation, no curd
5	2.11 : 1	28.23	Curdy, small lumps of curd, no separation
6	2.25 : 1	20.10	Curdy, lumps of curd, no separation

Total solids in fresh milk, 13.40 per cent.
Acidity in fresh milk, .17 per cent.

These experiments show that, in this particular factory, a hard curd is formed in the evaporated milk when the concentration is carried as far as 28 per cent solids. They further show that there is a distinct difference in the behavior of the

milk at different times of the year. In spring or early summer there is a greater tendency for curdy milk than later in the season. Unfortunately the intervals between the samples of the June experiment are too great to show exactly when the formation of the curd begins, but the sample containing 28.02 per cent solids showed such a curdy condition that it strongly suggests that that milk would have been curdy at a considerably lower degree of concentration. In the Augnst milk curdiness started with 27.33 per cent solids, and in the November milk with 28.23 per cent solids.

In June the fresh milk contained .16 per cent acid, in August .12 per cent, and in November .17 per cent. The greater curdiness in the June milk could, therefore, not have been due to the higher acid content of that milk, but it may have been due to the peculiarity of the casein in milk coming largely from fresh cows, or to the feed, or to both of these factors.

The results of these experiments agree very closely with the general experience in the manufacture of evaporated milk. Milk in early summer is more difficult to process, owing to its tendency to become curdy, than milk processed at any other time of the year.

The experiments above described related to the conditions at one factory only. Other factories may and do have other conditions, and experiments in some of them would undoubtedly yield different results. It has been experimentally shown that, in some localities and at certain seasons of the year, a marketable evaporated milk cannot be made when the product is condensed sufficiently to contain over 24 per cent solids.

STERILIZATION AND KEEPING QUALITY

The temperature to which the milk is exposed during the condensing process destroys many of the microörganisms present in the fresh milk, but some of the more resistant forms are

not killed and there is also more or less chance for contamination before the condensed milk is put into the tin cans and hermetically sealed. Unless these organisms are killed they will multiply rapidly and spoil the product. It is therefore necessary that the milk be completely sterilized after it has been sealed in the cans. This is done by subjecting it to steam heat under pressure in a large sterilizer or autoclave, as described on page 461. The temperature used and the time of exposure must be sufficient to absolutely insure complete sterilization. If this process is properly done, the milk may be kept almost indefinitely. Incomplete sterilization has been the cause of severe financial losses to the manufacturer of unsweetened condensed milk.

COMPOSITION

Richmond gives the composition of unsweetened condensed milk as follows:

Sample	Water	Fat	Milk-sugar	Protein	Ash
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
1	63.47	10.22	12.98	10.30	2.07
2	62.40	11.91	13.04	9.68	2.14
3	63.07	10.86	13.38	9.80	2.21

TESTING UNSWEETENED CONDENSED MILK

The ordinary Babcock method has been recommended for determining the percentage of fat in evaporated milk, but Hunziker[1] found that this method did not give satisfactory results. He recommends the following modifications of the Babcock method as giving accurate and satisfactory results.

Directions for Modified Babcock Test with Unsweetened Condensed Milk (Hunziker)[1]

APPARATUS:

One cream balance.
One 17.6 c.c. pipette.
One 17.5 c.c. acid measure.
One 50 c.c. glass beaker.
Ten per cent milk test bottles.
One Babcock centrifuge.
Commercial sulfuric acid, specific gravity 1.82 to 1.83.

Manipulation of test. Carefully weigh 4.5 grams of well-mixed evaporated milk into the 10 per cent test bottle. Add one pipetteful of water. Add 17.5 c.c. of sulfuric acid and shake until the curd in the test bottle is completely dissolved. Whirl at usual speed (900 to 1000 revolutions per minute) for five minutes. Mix equal portions of water and sulfuric acid in glass beaker. For one or two tests one pipetteful of water and one acid measure full of acid is sufficient. Fill test bottle to the zero mark with this hot diluted acid. Whirl for two minutes in tester, fill bottles to about the 8 per cent mark with hot water, whirl for one minute and read the test at 140° F. The fat column must be read from the top of the upper meniscus to the bottom of the lower meniscus. Multiply the reading by 4. This gives the correct per cent of fat.

For making numerous tests from the same sample it is advisable to dilute the evaporated milk with equal parts of water, by weight; then weigh nine grams of this dilution into the test bottles and add one-half pipetteful of water.

RAPID METHOD FOR DETERMINING SOLIDS IN UNSWEETENED MILK [1]

Hunziker worked out a formula for calculating the percentage of solids when the per cent of fat and the Beaumé hydrometer reading at 60° F. were known. The formula is as follows:

$$\left[\left(\frac{145.5}{145.5 - B}\right) \times 1000 - 1000\right] \times \frac{1}{4} + 1.2 \times F$$

B = Beaumé hydrometer reading
F = per cent of fat

Example: Evaporated milk tests 7.8 per cent fat and the Beaumé reading at 60° F. is 8.4.

[1] Indiana Report 1913, p. 43.

The per cent of solids =

$$\left[\left(\frac{145.5}{145.5 - 8.4}\right) \times 1000 - 1000\right] \times \tfrac{1}{4} + 1.2 \times 7.8 = 24.68$$

per cent solids

SWEETENED CONDENSED MILK

The process of making sweetened condensed milk is very similar to that used for making the unsweetened product. The chief difference is in the addition of the sugar and the omission of the sterilizing process. The sweetened milk is not sterile, its keeping quality being dependent upon the concentration of the milk solids and the preservative action of the added cane-sugar. For this reason the concentration is usually carried somewhat farther than in the case of the unsweetened goods. It is also important that the sugar be as free as possible from bacteria spores, yeasts, and molds, which might develop later in the finished product, causing fermentation changes and the spoiling of the milk. If it is not sufficiently concentrated, or too small a percentage of sugar is added, there is more danger of the finished product not keeping well. The greater the concentration and the larger the percentage of cane-sugar used, the better will be the keeping quality of the finished product. On the other hand, the nearer the finished product resembles fresh milk in composition, the greater its commercial value, and the more cane-sugar added, the greater will be the difference in composition between the fresh and the condensed milk. Manufacturers have learned from experience the limits between which it is safe to vary the degree of concentration and the amount of cane-sugar.

Richmond gives the composition of sweetened condensed milk as follows:

Composition of Sweetened Condensed Milk

(Condensed Whole Milk)

Sample	Water	Fat	Milk-sugar	Cane-sugar	Protein	Ash
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
No. 1	24.06	11.28	13.97	38.31	9.36	2.13
No. 2	26.10	10.84	14.68	36.93	9.55	1.90
No. 3	25.69	10.98	16.29	32.37	12.33	2.34
(Condensed Skim-milk)						
No. 4	29.05	1.28	14.91	40.07	10.63	2.33
No. 5	29.23	0.64	15.50	40.19	10.73	2.63
No. 6	28.43	0.36	16.88	39.27	11.73	2.58

USES OF CONDENSED MILK

The different kinds or grades of condensed milk are used for many purposes. Most of that which is put up in small, sealed cans, both sweetened and unsweetened, goes for household uses. While it is quite commonly used in the cities for use in coffee or for feeding infants, its chief uses are in sections where fresh milk cannot be obtained. Large amounts are used in hot climates, for the army and navy and for ocean voyages, and large quantities are exported. The condensed milks which are sold in bulk are used for manufacturing purposes, large quantities being used by bakeries, candy makers, and ice cream manufacturers. Condensing makes it possible to conserve the surplus production of early summer for use during the fall and winter when the supply of fresh milk does not equal the demand.

POWDERED MILK

The reasons for making powdered milk are the same as for making condensed milk; namely, reduction of bulk and cost of transportation and increase in keeping quality. In the case

of the powdered milk the drying process is carried much farther than with condensed milk. The finished product contains all the solids in the original milk, but so small an amount of moisture that bacteria and other microörganisms are unable to grow. It is therefore not necessary to use additional sugar or to sterilize the finished product by heat. Powdered milk contains not more than three to five per cent of moisture, and bacteria which may be present in it are unable to grow, hence cannot injure the product.

The making of powdered milk is of much more recent development than that of condensed milk, since this branch of the dairy industry has all developed during the last twelve or fifteen years.

PROCESS FOR MAKING POWDERED MILK

Several methods are in use for making powdered milk. "One [1] is the 'Just' process which was invented by John A. Just of Syracuse, New York. The milk is dried on steam-heated cylinders which as they revolve are given a coating of liquid milk. The heat conducted from the inside evaporates the water and leaves the solids in a dry layer on the surface, from which they are scraped off with knives which extend the full length of each cylinder. The strong point of this process is its cheapness.

"The rights for this process were sold to a man by the name of 'Hatmaker' for operations in Europe. On that account this process is known in Europe as the 'Hatmaker' process. By this method the milk is subjected to very high heat which affects its solubility."

Another method is that known as the "Campbell" process. By this system of drying warm air is blown through the milk until it becomes very thick. It is then exposed to hot air and

[1] Data by R. S. Fleming.

the drying process completed. After the drying is completed the milk is ground into flour.

The Ekenberg process. — This process was invented by Dr. Martin Ekenberg of Stockholm, Sweden. The patents concerning this process are owned by the Ekenberg Company of Cortland, New York. The first powdered milk made by this process in this country was made at the Cortland plant in 1905. The company now operates a number of factories in New York and Michigan.

"Dr. Ekenberg's process[1] consists of complete drying of milk in a vacuum machine known as an exsiccator. In this process the milk is first sprayed upon the bowl-shaped ends of a revolving drum. In this step of the process a considerable amount of moisture is removed. The condensed milk resulting is then sprayed upon the cylindrical surface of the drying drum and the remaiuiug moisture is removed during one revolution of the drum. Knives or scrapers haviug a bearing upon the surface of the drum cut the film of dried milk from the drum and it falls in a film iuto a receiviug chamber, which is separated from the large dryiug chamber by two air-tight gates or locks, thus providing for the removal of the dried product without breaking the vacuum or stopping the process. This arrangement of product chambers and locks permits of a continuous operation of the machine.

"After the product has been removed from the exsiccator it is cooled and then milled upon specially constructed mills.

"By this process different grades of milk are manufactured, ranging from skim-milk to whole milk, aud eveu milk containing more than the normal amount of butter-fats. They also use the exsiccator in the manufacture of malted milk and malted buttermilk, the latter being used in Teco prepared flours, used for pancakes and other purposes.

[1] Data by L. P. Bennett.

COMPOSITION

"The chemical composition of the skim-milk powder which is designated as A Grade Ekenflor and of the whole milk powder designated as Grade W Ekenflor is approximately as follows:

	Skim-milk	Whole Milk
Albuminoids	34–35 per cent	25 per cent
Milk-sugar	51 per cent	40.0 per cent
Ash	7.5–8 per cent	5.3 per cent
Moisture	4 per cent	3.0 per cent
Butter-fat	—	25–27 per cent

"A modification of this process in which the milk is condensed in a vacuum pan before being placed on the cylinders in the drying chambers is known as the 'Passburg' system."

The Merrell-Soule process.[1] — In 1905 the Merrell-Soule Company of Syracuse, New York, introduced what is now known as the "spray process" for drying milk. The fundamental principles of desiccation by spraying into a current of warm air were covered by a patent granted to Robert Stauf, a German, in 1901. Merrell-Soule Company purchased this patent in June, 1905, believing it to be the basic patent of this comparatively new art. This confidence was well placed, for the patent, number 666711, has been passed upon favorably by both lower courts and a Court of Appeals.

The claim in this patent describes the process in the following manner: "The process of obtaining the solid constituents of milk, in the form of powder, said process consisting in converting the liquid into a fine spray, bringing such spray or atomized liquid into a regulated current of heated air so that the liquid constituents are completely vaporized, conveying the dry

[1] Data by R. S. Fleming.

powder into a suitable collecting-space away from the air current *and discharging the air, a vapor, separately from the dry powder.*"

After operating under the Stauf patent for about a year, it was seen that a great economical advantage would be effected by condensing the liquid milk in a regular vacuum pan previous to spraying it into the air current. This step was patented July 23, 1907.

The spray process is adaptable to the desiccation of a great variety of milk products. The first tried out, and for a long time the only highly successful one, was skim-milk. Whole milk, although easily dried, spoiled quickly through the development of rancidity. Much study and patient research was applied to this problem. Step by step the various factors which produce rancidity were determined. With each step there was an improvement in the keeping qualities, until to-day whole milk can be manufactured to keep nicely for from six months to a year. Not only whole milk but all grades of milk up to 18 per cent cream are now successfully dried. The following table gives the composition of several of these dried products.

	Butter-fat	Casein	Albumin	Milk-sugar	Ash	Moisture
Skim-milk	1.35	29.79	7.91	49.94	8.21	2.40
Half skim	14.20	25.56	6.70	44.41	7.01	2.12
Whole milk	28.20	21.22	5.45	47.88	5.75	1.50
15% "Cream"	65.15	10.60	2.82	17.86	2.91	.66
18% Cream	70.47	9.08	2.42	15.01	2.46	.56

It will be noted that powdered cream has a butter-fat content approaching very closely to that of butter itself.

Not only is the spray process applicable to such products as the above, which differ from each other mainly in their butter-

, but it applies equally well to a variety of milk and compounds such as soluble casein, whey, ...k, and modified milk. One of the most successful of these dried products is powdered modified milk. This is a milk intended especially for infant feeding. It is made from whole milk, blended with cream and sweet whey in such proportions that the casein content is decreased while the lact-albumin and milk-sugar are increased to such a degree that the product closely resembles human milk. The analysis of this dried product both in the dry and restored state is given below. For comparison an analysis of human milk is also given.

	Dry	Restored	Human
Butter-fat	18.20	2.28	3.3
Casein	8.51	1.06	1.0
Albumin	7.43	.93	.5
Milk-sugar	57.37	7.17	6.8
Ash	7.28	.91	.2
Moisture	1.21	87.65	88.2
	100.00	100.00	100.00

Another milk product which has just recently been successfully dried by the spray process is buttermilk. Heretofore creamery buttermilk has been largely a waste material. At best it was used as hog or chicken feed. It is now being dried and sold for baking purposes. It differs from skim-milk in its high percentage of lactic acid, and considerable amount of butter-fat. Both of these add to its value in baking. The composition is approximately as follows:

Butter-fat	8.0
Protein	34.0
Milk-sugar	40.0
Lactic acid	6.0
Ash	9.5
Moisture	2.5
	100.00

Powdered milk has many advantages over liquid milk. First of all there are the keeping qualities. Whereas liquid milk at the best will keep only a few days, dry milk will keep many months. In fact, some grades of it properly protected from moisture, etc., will keep indefinitely. No bacterial action so far as we have been able to determine takes place in the dry product. There is rather a tendency for such bacteria as are present to slowly die off. The question of bacteria is entirely one of proper control up to the moment when the milk is dried. That it is possible to exercise this control is shown by the results of counts made on daily samples covering long periods of time. During the past year something like 2800 dry samples were counted in the Merrell-Soule laboratory. Of these 96 per cent were below 25,000 per c.c., and had an average of about 2000 per c.c., figured to the liquid basis.

One of the big factors in the present high cost of milk is that of transportation. When we remember that seven-eighths of milk is water, it is at once apparent that if we eliminate the water we save seven-eighths of the cost of transportation. The dried product may be shipped by freight, while liquid milk must go by express. This means an additional saving in favor of the dried article.

The spray process of drying milk presents some very important advantages over other processes. These advantages are not all apparent at first. In fact, it is a question whether the original inventor fully realized the importance of his discovery. Chief of these is the rapidity with which evaporation takes place. We have every reason to believe that each particle of liquid as it is shot through the air gives off moisture so rapidly that the milk solids are kept in a cool condition until perfectly dry. This is in accord with the well-known physical law that the evaporation of liquids uses up heat. In the ordinary condensation of milk it is well understood that if concentration be carried beyond certain limits there is an injury to the milk

solids. There seems to be a critical stage somewhere between high concentration and dryness where prolonged heating does much damage. With the spray process this stage is passed through instantaneously. After the dry condition is reached, comparatively high temperatures will do no harm.

Whether the above reasoning is correct or not, the fact remains that milk dried by the spray process, in distinction from other processes, retains all its natural properties. On the addition of water it goes back to its original state. There is no sediment. The casein retains its colloidal structure. The albumin is not coagulated. The butter-fat is in complete emulsion in its natural globular form. The enzymes are still active. In fact, as far as we know the restored milk is identical in properties with the original milk.

The uses for powdered milk are many. Skim-milk is used by the bakers for bread, biscuits, cakes, and custards; whole milk for the higher grades of cakes and biscuits. The ice-cream manufacturer uses skim-milk powder for giving "body" and smoothness, and cream powder for richness. The confectioner mainly uses whole milk and cream powders for his caramels, milk chocolates, and fudges. Certain grades are also used in making prepared flours.

It was natural that the food manufacturers should be the first users of milk powder. They are accustomed to consider cost, quality, flavor, and uniformity. For these reasons the dry milk appealed to them. Creamery men are extensive users of skim-milk powder for starter-making purposes and for artificial buttermilk.

METHODS OF MARKETING

Powdered milk is put on the market in packages holding 25, 50, and 100 pounds and in barrels holding 200 pounds. As yet powdered milk is not very generally used for household purposes, but limited amounts are put up in 1, 5, and 10 pound cans for retail trade.

DEFINITIONS AND STANDARDS

The following definitions and standards for powdered milks have recently been adopted by the joint Committee on Definitions and Standards of the American Association of Dairy, Food, and Drug Officials and the Association of Official Agricultural Chemists:

"*Dried milk* is the product resulting from the removal of water from milk, and contains, all tolerances being allowed for, not less than twenty-six per cent (26.0 %) of milk-fat, and not more than five per cent (5.0 %) of moisture.

"*Dried skim-milk* is the product resulting from the removal of water from skim-milk and contains, all tolerances being allowed for, not more than five per cent (5.0 %) of moisture.

"*Malted milk* is the product made by combining whole milk with the liquid separated from a mash of ground barley, malt, and wheat flour, with or without the addition of sodium chloride, sodium bicarbonate, and potassium bicarbonate in such a manner as to secure the full enzymic action of the malt extract and by removing water. The resulting product contains not less than seven and one-half per cent (7.50 %) of butter-fat and not more than three and one-half per cent (3.5 %) of moisture."

CHAPTER XIII

FERMENTED MILK (Rogers)

WITHIN recent years there has been a rapidly growing interest in the therapeutic value of buttermilk and other fermented milks, such as kefir, kumiss, and yogurt. This is seen in the increasing sale of buttermilk, in the large number of special preparations now offered for sale, and in the frequent discussion of this subject in popular and scientific publications. Buttermilk is not only consumed in large quantities as a beverage, but is recommended by physicians as a therapeutic agent in the treatment of intestinal disorders, and is in constant use in many hospitals.

All the more familiar fermented milks are the result of an acid fermentation in which the sugar of the milk is split up into lactic acid. This may be brought about by the presence in the milk of varieties of the common lactic acid group of bacteria, or, as in the case of yogurt, by special organisms; or a yeast may be present, adding an alcoholic to the ordinary acid fermentation.

In many large cities special fermented milk preparations can be obtained under various trade names, such as zoulak, vitallac, yogurt, matzoon, bacillae, kefir, kumiss, and lactobaciline. These are all soured milks which have been introduced from southern Russia, Turkey, and neighboring countries. They are sold as freshly prepared milk, or in the form of tablets or powders in capsules which may be taken as such or used to ferment milk. These preparations have been widely advertised and are the subject of very positive statements in regard to the benefits derived from their use.

THERAPEUTIC VALUE OF FERMENTED MILK

Fermented milks have been used ever since very early times, but it is only within very recent years that physicians have become interested in the possibilities of their use for therapeutic purposes. Within the past twenty years there has been an increasing number of papers in the medical journals on this subject, and at one time the widespread popular interest in fermented-milk therapy was reflected by the numerous magazine and newspaper articles on various phases of the subject. This interest was stimulated in a large measure by the work of Metchnikoff and his associates. His views, which are set forth in some detail in Chapter V, "Lactic acid as inhibiting intestinal putrefactions," of his book entitled The Prolongation of Life, are looked upon by the more conservative investigators of this country as overdrawn and as unsupported by experimental evidence. In this book great stress is laid on the longevity of the people of certain countries in which fermented milks are an important part of the diet.

In considering evidence of this kind it should be remembered that many other things may contribute to the general health and vigor of the people, and that these factors cannot be excluded in drawing the conclusions. The people who habitually consume large quantities of fermented milk usually live a simple life, largely in the open air, and we have no means of knowing how much this may have contributed to the vigorous old age frequently observed among them.

The use of fermented milks as a therapeutic agent is based on tbe assumption that they are able to combat the so-called autointoxieation caused by the undue accumulation in the body of toxic substances emanating from the intestinal tract. The theory of autointoxication may be stated briefly as follows: The digestive tract of the human being is at birth free

from bacteria, but in various ways, chiefly through the food, many kinds of bacteria are introduced into the alimentary canal. In the intestines and particularly in the large intestine some of them find favorable conditions for growth and become established there in large numbers. In the normally nourished infant the bacterial varieties are limited in nuuber and for the most part consist of acid-forming types which by the active fermentation of thc milk-sugar furnished in large quantities in the food produce conditions under which bacteria of the putrefactive type are unable to multiply to any extent. The predominance of an acid fermentation in the large intestine produces an acid stool with a characteristic but comparatively unobjectionable odor. As the child gets older the variety of food is greater and the relative proportion of carbohydrates to protein is much reduced. In place of the acid fermentation there is a decomposition of the proteiu by other bacteria, intestinal gas is produced, and the stools become alkaline and frequently have a very objectionable odor. In the bacterial decomposition of the predigested protein it is supposed that products of a more or less toxic nature are produced. When the quantity of these products is relatively small, they are disposed of through the normal channels and have uo appreciable effect. If the excretory system fails to do its normal work, or if the protein decomposition is unusually active, toxic substances accumulate and the symptoms of autointoxication are produced. The production of toxic substances in abnormal amounts may be caused by a combination of circumstances promoting an unusual activity of putrefactive bacteria normally present, or it may be because the bacterial flora of the intestines changes and new bacteria are introduced.

The method of treating this condition by the use of sour milk is based on three conditions which may be stated as follows: (1) it assumes as correct the theory of the production of toxic substances in the intestine by the action of bacteria in quan-

tities sufficient to cause the symptoms of autointoxication; (2) the putrefaction or fermentation through which these toxic substances are produced can be suppressed by other bacteria; and (3) the bacteria which it is proposed to use in suppressing the putrefactive bacteria may be introduced into the intestines and will be able to establish conditions there under which they will multiply and persist, while the objectionable types are driven out.

The standing of the theory of autointoxication mentioned under the first condition cannot be discussed in detail in a book of this nature. It may be said, however, that the question of autointoxication, in its broader sense, is not nearly so simple as it is stated here. It is at best only a theory, and much investigation of details will be necessary before its position can be determined.

The second condition is easily demonstrated, not only by scientific observations, but also by many instances in our daily life. Vinegar, which is used in pickle-making, owes its preservative action to the acetic acid produced by a bacterial fermentation; when milk sours spontaneously, the acid-forming bacteria develop acid so rapidly that in a short time all other bacteria are inhibited. Observations of this kind could be multiplied almost indefinitely. In fact, in the bacterial world, as among the higher plants in their natural state, there is a constant struggle for mastery in which the types best suited to their environments, or, perhaps more correctly, less sensitive to the unfavorable conditions which they themselves produce, gain the ascendency and more or less completely suppress other forms.

The particular bacterium which it is proposed to use in suppressing the putrefactive bacteria of the intestines is the organism commonly known as *Bacillus bulgaricus*, or the Metchnikoff bacillus. It is characterized by its ability to form acid in exceptionally large amounts from sugars, particularly milk-sugar.

When milk containing bacteria of this type is held under conditions favorable to its growth, the acid produced will inhibit other forms and the milk will eventually become a practically pure culture of the *Bacillus bulgaricus*. There can be no question that, under conditions favorable to its growth, this bacterium is able to suppress very effectively other kinds of bacteria, even many of those which produce an acid fermentation. This is well illustrated in the manufacture of cheese of the Emmental or Swiss type. Cheese made by this method from milk containing gas-forming bacteria will become filled with gas bubbles in the press. If a comparatively small amount of a culture of the *Bacillus bulgaricus* is added to this milk, the high temperature at which the cheese is held promotes its vigorous development, and the gas formers are completely suppressed.

There is little doubt that if this organism could be established in the large intestine under conditions favorable to its growth it would soon produce a state of affairs which would at least inhibit the growth of the bacteria that usually decompose the proteins. The evidence that this takes place, even when large quantities of the bacteria are ingested, is by no means conclusive. On the one side the associates of Metchnikoff have produced considerable evidence to show that when *B. bulgaricus* is taken into the digestive system it becomes established in the intestines, where it persists for some time after the feeding ceases. Cohendy, who fed four patients for extended periods on milk curdled with *B. bulgaricus*, concluded that this organism was readily established in the intestines, and that it persisted there for a considerable time after the subject had ceased to take fermented milk. This was said to be especially true if a diet containing suitable nourishment for the ingested organism was adopted. It is stated that the multiplication of these bacteria took place in the upper two-thirds of the colon. The stools were acid or neutral.

The same writer in another paper shows that intestinal putrefaction as indicated by the excretion of ethereal sulphates in the urine was materially reduced by the addition of a sour milk to the diet and that this reduction, which may reasonably be attributed to a disinfection of the large intestine, continued after the ingestion of sour milk was discontinued. This may be taken as an indication that the growth of the bacteria continued after their introduction ceased. This disinfecting action of the lactic acid culture was not appreciably influenced by variations in the amount of sugar eaten, indicating that the ordinary diet contains sufficient sugar to support the growth of the lactic acid bacteria in the intestine.

Belonovsky arrived at somewhat similar results in experiments in which mice were fed a basic ration of sterilized grain and water. Mice which received in addition milk cultures of *B. bulgaricus* for one and one-half months showed this organism in the droppings 15 days after the last feeding. When the milk cultures were fed for four months, *B. bulgaricus* was present in the droppings for four weeks after the last feeding. He states that the bacteria in the droppings, especially the gas-forming bacteria, were very much reduced by feeding *B. bulgaricus*, but were not affected by the addition of the basic diet of sterile milk or milk curdled with lactic acid.

Many experiments of a similar nature could be quoted, as well as clinical observations, tending to show that the ingestion of milk cultures of *B. bulgaricus* reduces or eliminates evidences of intestinal putrefaction. On the other hand, Herter found that in the digestive tract of a monkey, killed after feeding for two weeks on milk soured with *B. bulgaricus*, this organism was abundant in the upper part of the small intestine only. In the lower part and in the large intestine *B. bulgaricus* was present in only moderate numbers as compared with other bacteria.

Rahe, in a recently published paper, maintains that the difference between the *B. bulgaricus* and certain acid-forming

bacteria, which are known to occur normally in the intestines, is so slight that they can be distinguished only with difficulty, and he suggests that belief on the part of some investigators that *B. bulgaricus* becomes established in the intestines was caused by their inability to distinguish between these two types. His work tends to show that while the *B. bulgaricus* appears in the feces during the feeding, it persists for only a few days after the ingestion of cultures ceases.

The situation may, perhaps, be fairly summed up by saying that while there is no conclusive evidence that *B. bulgaricus* is able to establish itself in the intestines in such a way that other bacteria are driven out, it is undoubtedly true that in many cases marked improvement has resulted from the ingestion of milk cultures made from it. It is by no means certain, however, that the results which have been obtained by the use of milk cultures have been attributable to any peculiar virtue in the organism itself. It has been held by some investigators that the intestinal flora may be radically changed by a fundamental change in the diet.

Distaso and Schiller state that when rats were fed a diet of lactose and dextrine the heterogeneous intestinal flora was changed to one consisting almost exclusively of *Bacillus bifidus*, the characteristic acid-forming bacillus of the intestines. This is in accord with the earlier work of Herter and Kendall, who found that the nature of the bacterial flora of the intestines could be promptly and distinctly changed by a radical change from a diet high in protein to one in which carbohydrates predominated, or vice versa. A high-protein diet caused symptoms of intestinal putrefaction. A change to a carbohydrate diet resulted in a reduction of the putrefactive bacteria, an increase in the acid-forming bacteria, and the disappearance of the indications of autointoxication. Similar results were obtained in an investigation carried on by Rettger. This work was very comprehensive, covering a long series of

experiments with chickens and white rats, and the results if accepted will make it necessary to revise the commonly accepted views of the physiological actions of sour milk. Rettger found that when chicks were fed milk not only was the percentage of mortality materially reduced, but the rate of growth was greatly increased. Practically the same results were obtained whether sweet or sour milk was fed, and there was no appreciable difference in the results obtained by feeding milk soured by *Bacillus bulgaricus* and the common lactic forms. The probable explanation of this fact was found in the experiments with white rats, in which a study was made of the intestinal bacterial flora during the feeding experiments. It was found that when the rats were fed a diet which included milk, the usual mixed bacterial flora of the intestines was replaced almost completely by two types of bacteria which resemble the *Bacillus bulgaricus* very closely, especially in their physiological characteristics. Identical results were obtained when the milk was displaced in the diet by milk-sugar.

The conclusion seems obvious. The bacteria of the high-acid type, which are apparently normally present in the intestines, are stimulated by the unusual amount of milk-sugar furnished by the milk diet, and multiply to such an extent that the ordinary mixed flora is suppressed.

The beneficial effect of a sour-milk diet is attributable, perhaps, not so much to the bacteria contained in the milk as to the milk itself, which provides material for an acid fermentation in the intestines.

Milk is usually looked on as a nitrogenous food, but it should be remembered that it contains about 5 per cent of lactose, a carbohydrate which seems to be peculiarly adapted to bacterial fermentation.

Aside from the possible therapeutic value of fermented milks, there can be no question that they are nutritious and refreshing and that their use should be encouraged for their food value.

FOOD VALUE OF FERMENTED MILK

...igh food value of milk is too generally recognized to need discussion here; fermented milks also have a high food value, except that in some cases the fat is partially or entirely removed. Otherwise the food value of the fermented milk differs little from that of the fresh milk from which it is made. Any increased digestibility of the fermented milk is due not so much to change in the chemical nature as to the fact that the casein is furnished in a precipitated and finely divided condition. In none of the fermented milks is there any material cleavage of the casein resembling the digestion in the stomach. The fat is practically unchanged, and a part only of the sugar is converted into acid, alcohol, or gas. In certain gastric troubles in which it is difficult to find any food that can be retained by the patient, fermented milks are frequently used with good results. Kefir and kumiss especially are used under such circumstances, as the stimulating action of the carbon dioxid which they contain is believed to aid in their digestion. To the physician the value of a highly nutritious food which can be digested when other foods are rejected is obvious.

There are many questions that should be very carefully considered before a fermented milk is introduced as an important part of the diet. As Herter has pointed out in the admirable paper already cited, the addition of fermented milk to the diet may change very materially the ratio of protein to other classes of food. If the milk is taken in place of other food, the daily protein ration may be so reduced that intestinal putrefaction, which is dependent on the protein part of the food, is diminished. On the other hand, if milk is added to the usual food, the protein ratio may be increased rather than diminished. In many cases the condition of the mucous membranes will not permit the presence of organic acid, and soured milk cannot be retained. It is also possible

that symptoms of autointoxication are not caused by unusual bacterial activity in the intestine, but by functional failure of certain organs. This point could be determined only by a physician. It would be very unsafe to consume large quantities of milk, fermented or unfermented, under certain pathological conditions. In any case an important change in the diet should be made only upon the advice of a physician.

THE VARIOUS FORMS OF FERMENTED MILK

If it is considered advisable to use cultures of acid-forming bacteria, the form in which they are taken becomes an important question. In large cities one usually has a choice of lactic acid bacteria from several sources. Buttermilk is usually available, although it is not always of good quality. Sometimes kumiss or kefir can be obtained, and at the present time milk coagulated with the so-called Metchnikoff bacillus is sold as yogurt or matzoon and under various trade names.

Cultures in tablet and capsule form

In addition to these freshly prepared preparations several tablets or capsules purporting to be pure and active cultures of the *Bacillus bulgaricus* are now offered for sale (see Fig. 88). These are for use in fermenting milk or are to be taken directly in place of buttermilk or yogurt. Herschell in his little book on the therapeutic uses of soured milks recommends the use of these preparations in preference to fermented milk, but it should be noted that he is very ex-

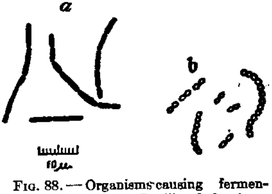


FIG. 88. — Organisms causing fermentation of milk. *a*, *Bacillus bulgaricus*; *b*, lactic acid bacteria.

plicit in his statement that great care should be taken to determine the abundance and purity of the desired organism. *Bacillus bulgaricus* seems to be particularly sensitive to desiccation. When preparing the material in tablet form, therefore, a high percentage of the organisms is usually killed, whereas foreign organisms commonly retain their viability. Even when prepared with the best of care, such tablets lose their efficiency so quickly that unless they are used within a time limit of efficiency guaranteed by the maker the results may be disappointing.

It is very easy to test the purity and activity of these dried cultures. Thoroughly pasteurize a small quantity (about half a pint) of milk by holding it, in a bottle plugged with cotton, at or near the boiling point for an hour or more. When this has cooled, add two or three of the tablets and keep in a very warm place overnight. It should not be below and may be a few degrees above blood heat. If in this time the milk has not curdled with a sharp, acid taste and without gas bubbles and whey, there can be no reason for using these tablets except the possibility that they contain the active element of the culture which retards the growth of other bacteria. The evidence on this point is so inconclusive that it need not be considered in this connection.

All reliable manufacturers now place the date of manufacture on each package and state the time within which the tablets should be used.

Buttermilk

Buttermilk, properly speaking, is the by-product resulting when milk or cream is churned for butter. It is the milk remaining after the fat which collects in granules is removed. If cream is churned when sweet the buttermilk does not differ from ordinary skimmed milk, but if it is churned when sour

— the usual practice — the acidity is sufficient to coagulate the casein in the cream. In the churning process this curd is broken up into very fine particles. These curd particles settle very slowly, and if the buttermilk is agitated occasionally it will retain its milky appearance. When the buttermilk is allowed to stand undisturbed for several hours, the curd particles sink to the bottom, leaving an opalescent whey at the top. At the present time a large part of the so-called "buttermilk" sold in cities is not buttermilk, properly speaking, since it is not made by churning cream, but is simply soured skimmed milk which has been churued or stirred in order to break up the curd. The same product is sold also under the name of "ripened milk."

The souring of milk or cream is brought about by the activity of certain bacteria which form lactic acid by decomposing the milk-sugar (lactose). The ability to form acid from lactose and other sugars is possessed by mauy kinds of bacteria, but is so characteristic of a certain group that they are commonly spoken of as the lactic acid bacteria. These bacteria have been described as distinct species or varieties under many names. Among them may be mentioned *Bacterium guntheri*, *Bacillus acidi lactici*, and *Streptococcus lacticus*. In spite of the confusion in nomenclature it is evident that the term "lactic acid bacteria" includes a fairly well-defined group of closely related varieties possessing in common several definite characters. Variations from the type in minor characters produce an almost infinite number of varieties. These variations may be in the ability to ferment different sugars, in the tendency to grow in chains, in the kind of flavor formed in milk, in the intensity of acid formation, and in the ability to produce pathological conditions in animals.

In many creameries the cream is allowed to sour spontaneously. In this case many bacteria other than the true lactic bacteria will take part in the acid formation, and in addition

to lactic acid the buttermilk may contain in small quantities acetic, succinic, and formic acids, and sometimes traces of alcohol. The lactic bacteria form lactic acid, with only slight traces of other organic acids, no alcohol, and no gas. In well-managed creameries the acid fermentation is assisted and controlled to some extent by the use of a starter. This may be milk allowed to sour spontaneously, or buttermilk from the previous day's churning, but careful butter-makers build up starters from commercial cultures sold in the form of powders, tablets, or fluid cultures, as varieties of lactic acid bacteria selected with special reference to the production of a desirable flavor in butter. The butter-maker puts this culture into about a quart of milk which has been steamed for an hour or more to reduce the bacteria to the lowest possible number. After standing overnight the milk will usually be curdled, but gas bubbles and other evidences of contamination may be observed. A small portion of this milk is transferred to another bottle of milk prepared as before, and this process is continued until the acid fermentation has become sufficiently active to eliminate the contaminating bacteria, and the milk curdles with a clean, acid taste and without signs of gas or "wheying off." This small starter, or "mother starter," is carried along indefinitely by daily transfers to freshly steamed milk. If reasonable precautions are taken to prevent contamination after a thorough heating of the milk, this culture will remain pure and vigorous for an indefinite time.

To prepare the starter actually used in ripening the cream, a larger lot of milk — 25 to 50 gallons or more, according to the amount of cream — is heated for an hour or more. This is usually done in a special apparatus (sold by creamery supply houses) which consists of a large can inclosed on the sides and bottom by a steam jacket and fitted with a belt-driven stirrer. Milk either skimmed or unskimmed is heated by turning steam into the jacket; during the heating the milk is stirred con-

stantly. After the pasteurization is completed, cold water is run into the jacket and the milk cooled to about 24°–27° C. (75.2°–80.6° F.). A bottle of the mother starter is added and the can is covered and allowed to stand overnight. This gives a large and active pure culture of lactic acid bacteria to start the acid formation in the cream. Better results are obtained if the cream is first pasteurized.

When lactic acid bacteria grow in milk, the lactose is converted into lactic acid with slight traces of certain other organic acids. This acid breaks up the combination of calcium phosphate and casein which holds the casein in solution, and the casein is precipitated as a firm, jellylike mass. When this occurs in cream, the fat globules are entangled in the precipitated casein. In the process of churning the casein is broken into fine particles, and the fat globules are collected into large granules that float on the top of the buttermilk. Buttermilk, then, is the water of the milk holding the sugar, acids, ash, and other soluble constituents in solution and the finely divided particles of precipitated casein in suspension. The amount of fat in the buttermilk depends on the completeness with which the fat is removed in the churning. Even with the best methods a little of the fat in the form of very small globules remains in the buttermilk. On standing, the suspended casein settles slowly to the bottom.

The composition of an average buttermilk is about as follows:[1]

	Per Cent
Fat	0.5
Casein	2.4
Albumin	.6
Lactose	5.3
Ash	.7
Total solids	.95

[1] Vermont Agricultural Experiment Station. Annual Report, 1891, p. 119.

buttermilk differs but little from skim-milk. rearrangement is necessary to bring about the ...ge in the casein. If the milk has been pasteurized at a high temperature, the albumin is precipitated and the larger part lost. A small part — less than one-fifth — of the milk-sugar is converted into acid. This acid combines with the ash constituents, probably converting the triphosphates into diphosphates and monophosphates and the diphosphates into monophosphates. It is obviously not necessary to make butter in order to secure a perfect snbstitute for buttermilk. Soured skim-milk has all the chemical properties of buttermilk, and if it is thoroughly agitated in order to break up the curd it agrees in appearance and flavor with buttermilk obtained by churning cream.

In making buttermilk from milk, the same procedure should be followed as in making a starter for cream ripening. A good, clean-flavored mother starter should be carried along with every possible precaution to prevent contamination. Good commercial cultures can be obtained, but if it is not convenient to use one of these, a natural starter should be secured. For this purpose the following procedure may be followed:

(1) Select milk from several sources; put about 1 pint of each into clean glass jars or bottles and allow them to stand in a warm place until the milk is curdled.

(2) When this occurs, put about 1 pint of milk into each of an equal number of bottles and hold in steam or boiling water for one-half hour.

(3) When these bottles of milk are cooled, transfer about one teaspoonful of milk from each of the bottles of sour milk obtained in (1) to one of the bottles of heated and cooled milk.

(4) Allow these samples to curdle and repeat the process until one sample is obtained which curdles in at least eight or ten hours with a smooth curd free from whey and gas bubbles and with a pleasant, acid taste.

Gas bubbles, or the separation from the curd of a milky or straw-colored whey, show that the lactic acid bacteria are still mixed with other kinds. Considerable variation in flavor can be found in different cultures, and care should be exercised to select one that gives a clean and sharp taste.

(5) Propagate this culture in the same way from day to day. The amount of this mother starter which should be carried will depend somewhat on the amount of buttermilk to be made. One quart should be enough for 20 to 30 gallons.

(6) (*a*) Add the mother starter to the milk to be used for buttermilk, or (*b*) pasteurize the milk in a continuous pasteurizer at 180° to 185° F. (82° to 85° C.), or preferably hold the milk in water-jacketed vats or cans at 180° F. (82° C.) for thirty minutes to an hour; cool to about 70° F. (21.1° C.) and add the mother starter. The most desirable temperature for this fermentation is 70° to 75° F. (21.1° to 24° C.).

(7) When this milk has curdled, cool it at once to about 50° F. and churn thoroughly to break the curd into fine particles.

The buttermilk should be smooth, free from lumps, and show a separation of whey and curd only on long standing.

Milk to be used for making buttermilk should be fresh and clean flavored. Good buttermilk cannot be made from milk that is tainted or too old to be used for other purposes. Skimmed, partly skimmed, or whole milk, as desired, may be used.

A more nearly uniform product is secured if the milk is pasteurized. The scorched taste which results from pasteurization at a high temperature is not objectionable, as it is obscured by the acidity of the soured milk. The time of the inoculation may be arranged to suit the convenience of the maker and can be determined by experience in each individual case. Using the same culture and holding the temperature uniform, the amount of the starter can be adjusted to bring

the acidity to the curdling point at any definite time within narrow limits. The temperature of the milk should be between 21° and 24° C. (70° and 75° F.). More rapid development of acid can be obtained at higher temperatures, but at the lower temperatures the lactic acid bacteria are more successful in checking the growth of digesting and gas-forming bacteria. At lower temperatures and with a slower development of acid the casein is precipitated in a finer and more friable curd than at temperatnres inducing a more rapid acid production. As soon as a fine curd has been formed the milk should be cooled promptly to below 50° F. to prevent the contraction and toughening of the curd.

Buttermilk made in the usual way as a by-product of butter-making, and especially buttermilk obtained by churning pasteurized cream, is improved by mixing with it about 10 per cent of a skim-milk culture of the *Bacillus bulgaricus.* Directions for the preparation of this culture will be found on page 508.

This culture not only gives the buttermilk a sharper and more agreeable flavor, but on account of its viscous nature it gives it a smoother texture and prevents the separation of the curd from the whey. Detailed directions for the preparation of buttermilk by this method may be found in a circular of the Illinois Agricultural Experiment Station.

Making buttermilk in the home.

A more nearly uniform product can be obtained if it is made on a large scale, and if good buttermilk can be purchased from a reliable milk dealer at a reasonable price, it is not advisable to attempt to make it on a small scale. However, it is possible to make buttermilk in the home by following in a small way the directions for making buttermilk on a commercial scale. It is necessary first to secure a culture or starter, which is merely milk containing the lactic acid or sour-milk bacteria free or very nearly free from other kinds. These bacteria are

present in any normal milk, and it is only necessary to provide conditions favoring their growth to obtain them in a state of purity.

This may be done by following the directions on page 11 for obtaining cultures for making buttermilk on a large scale. When the culture is obtained, it will not be necessary to carry a small culture to inoculate a larger amount.

When the culture is obtained, proceed as follows:

(1) Heat 1 quart of milk, which may be skimmed, in a double boiler for at least one-half hour.

(2) Allow the milk to cool to about 75° or 80° F.

At this temperature the outside of the container will feel warm to the hand. Add one teaspoonful of the fresh culture, transfer to a bottle or covered fruit-jar, and put away in a warm place. One of the vacuum-jacketed bottles will be found very convenient for this purpose, because the milk can be held at a nearly constant temperature favorable to the growth of the lactic acid bacteria.

(3) On the following day shake the bottle thoroughly to break up the curd and put the product on ice to cool.

(4) Repeat the process, using a teaspoonful of the freshly curdled milk to inoculate the heated and cooled milk.

Butter-makers in the Northwest make a very refreshing and nutritious drink by adding sugar and lemons to buttermilk. As the casein is already precipitated, the acid juice of the lemon has no effect. Slightly more sugar and lemon juice are necessary than in making ordinary lemonade, and the mixture should be well iced.

Kefir

Fermented milks have evidently been extensively used for many centuries by the people of southern Russia, Turkey, the Balkan countries, and their neighbors. The natives have no records and few traditions of the origin of the milks they use,

probable that their preparation and use developed by accident and cumulative experience. One of the first of the fermented milks known to Europeans was the kefir, made from the milk of sheep, goats, or cows in the Caucasus Mountains and neighboring regions. Kefir differs from most of the fermented milks of the Mediterranean countries in that it is made from a dried preparation and contains considerable quantities of alcohol and gas. Kefir is made by many tribes under varying names, as "hippe," "kepi," "khapon," "kephir," "kiaphir," and "kaphir," all of which are said to come from a common root signifying a pleasant or agreeable taste.

For a large part of their food the mountaineers of the Caucasus depend on kefir, which they prepare in leather bottles made from the skins of goats. In the summer the skins are hung outdoors, either in the sun or in the shade, according to the weather, but in winter they are kept in the house. The bags are usually hung near a doorway, where they may be frequently shaken or kicked by each passer-by. Fresh milk is added as the kefir is taken out, and the fermentation continues. Made and propagated in this way, foreign bacteria become mingled with the essential bacteria of the grains, and abnormal and frequently disagreeable flavors result. When the milk is drawn off, in order to prevent the escape of gas, a string is first tied around the neck of the leather bottle, so that the small part wanted for use is held between the stricture and the opening. In the villages and the low country kefir is made in open earthen or wooden vessels, and most of the gas escapes.

Small, yellowish, convoluted masses are observed in kefir, which are called seeds or "grains." These grains consist of a central filament of two parts, of which the outer spreads out, forming the convoluted polyp-like exterior. These parts are built up one upon another, giving the large grains a coral-like appearance. The central part is made up of a mass of bacterial

threads. In the outer layer yeast cells are found mingled with the bacteria. When the grains are added to milk, they swell and increase in size by forming new grains. At the beginning of the fermentation they settle to the bottom, but in a short time they are carried to the surface by attached bubbles of gas. If the fermentation is active, a thick layer will be formed on the surface, but on shaking or stirring this layer settles again to the bottom.

The biology of kefir was studied by Kern in 1881, but, owing to the faulty technique of that day, his descriptions are evidently erroneous.

Freudenreich describes four organisms that he isolated from kefir grains. One of these was a yeast which he designated *Saccharomyces kefir;* this he found to grow best at 22° C. (72° F.), but not at all at 35° C. (95° F.). It ferments maltose and cane-sugar, but not lactose. It gives a peculiar flavor to milk, but causes no fermentation. The cells are oval, 3 to 5 microns by 2 to 3 microns. It is not identical with the ordinary beer yeasts. Two of the organisms were of the lactic acid bacteria type, but differed from them in forming gas in lactose media. The most interesting of the organisms described is a long, slender bacillus corresponding to one described by Kern as *Dispora caucasica* and to which Freudenreich gave the name *Bacillus caucasicus.* In morphology, failure to grow on ordinary laboratory media, and in high-acid production in milk, this bacillus resembles very closely the bacillus mentioned later, in connection with yogurt, as *Bacillus bulgaricus.* If Freudenreich's description is accurate, *B. caucasicus* differs from *B. bulgaricus* by forming gas from lactose and in being feebly motile. Gas was formed slowly at 35° C. and still more slowly at 22° C. (72° F.). No one of these organisms alone produced kefir, but when the four together were grown in milk typical kefir was produced on the first or second transfer.

According to the investigations of Nikolaiewa, three or-

always present in the fermented milk. One of *rium caucasicum*, which forms the filament of the vidently identical with Freudenreich's *Bacillus caucasicus*. This investigator considers this bacterium, with a torula yeast fermenting lactose, dextrose, and cane-sugar, as essential to the production of kefir. Other bacteria and yeasts are found in the grains and the fermented milk, but they are looked upon as contamination.

It is probable that kefir is produced under different circumstances by different organisms. Any combination of bacteria or of bacteria and yeast that will produce a lactic acid and a milk alcoholic fermentation in milk will make kefir, although to secure the most desirable flavor certain organisms may be essential.

Hammarsten shows in the following table the changes brought about in cow's milk by this fermentation:

CHEMICAL ANALYSIS OF KEFIR

	2 Days Old	4 Days Old	6 Days Old
Casein	2.570	2.586	2.564
Lactalbumin	.425	.405	.390
Peptones	.071	.089	.120
Lactose	3.700	2.238	1.670
Fat	3.619	3.630	3.626
Ash	.641	.624	.630
Lactic acid	.665	.832	.900
Alcohol	.230	.810	1.100

It will be observed that the changes were confined almost entirely to the lactose and its by-products. The casein remained unchanged and the increase in the peptones was insignificant. The lactalbumin decreased slightly. The casein of kefir is, according to this chemist, not especially soluble, but

may be more easily digestible because of its finely divided condition. The lactose diminished appreciably, and there was a corresponding augmentation of alcohol and lactic acid. A certain part of the lactose is consumed in the formation of carbon dioxid gas not included in this analysis.

The following directions are given for making kefir when the grains are available: The dry grains are softened by soaking in warm water, which should be changed several times. When the grains rise to the surface and become white and gelatinous, they are ready for use. One part of these grains is used to three parts of milk which has been thoroughly heated to destroy the bacteria already present. The bottles in which the milk and grains are placed should not be stoppered but should be protected from the dust by cloths, inverted cups, or plugs of cotton. They are held at a temperature at or near 14° to 16° C. (57° to 60° F.), and stirred or shaken frequently. After eight to ten hours the milk is strained through cloth and put into tightly stoppered bottles at the same temperature as before. The bottles should be shaken every few hours to prevent the formation of lumps of precipitated casein. The kefir is ready for use at the end of twenty-four hours; if held longer than this, it is advisable to keep it on ice to check the fermentation. The temperature at which the milk is fermented is important in controlling the relative amounts of alcohol and lactic acid. At higher temperatures the percentage of alcohol is increased, while as the temperature is lowered the alcoholic fermentation diminishes and the quantity of lactic acid formed is greater. After the fermentation is once started the grains may he discarded and new kefir made by adding one part of the fermented milk to three or four of fresh milk. In order to remove the grains the kefir should be strained through cheese-cloth, and after thorough washing to remove the curd the grains may be dried by exposure to the sun on pieces of blotting paper. In this condition they are said to retain their vitality for several

years, although many of the yeasts in the outer part of the grain are killed by the desiccation. It may be necessary to break up the grains with the fingers. When in the wet stage they should not be larger than a walnut.

Kefir grains cannot ordinarily be obtained in this country, but a good imitation of kefir can be made by carrying on simultaneously in sealed bottles an alcoholic and a lactic fermentation. Better results can be obtained by inducing the alcoholic fermentation in buttermilk. In this way it is possible to avoid much of the trouble from the formation of lumps of curd. If buttermilk is made for this purpose from whole or skimmed milk, careful attention should be given to the time of curdling and the breaking up of the curd. This is essential to a smooth, creamy kefir. Ordinary bread yeast may be used for the alcoholic fermentation, but as this yeast does not ferment lactose it is necessary to add cane-sugar to the milk.

(1) Obtain buttermilk from a dealer, or prepare it as directed on page 492.

(2) Prepare the yeast by adding a half teaspoonful of sugar to a 6-ounce or 8-ounce bottle of boiled and cooled water. Add half a yeast cake to this sugar solution and set in a warm place overnight. This will give an active culture of the yeast and obviate the necessity of adding the yeast cake directly to the milk. This yeast culture should be ready at the time the buttermilk is received or, if made at home, at the time it is curdled.

(3) Add 1 to 1½ per cent of sugar to the buttermilk.

On the quantity of sugar added to the buttermilk will depend the extent of the alcoholic fermentation. Theoretically about one-half of the sugar fermented may be converted into alcohol; that is, milk to which 1 per cent of cane-sugar has been added may contain after the fermentation one-half of 1 per cent of alcohol. The quantity of sugar added should be governed by the amount of carbon dioxid it is desired to have

in the finished product. This should be sufficient to make the kefir distinctly effervescent and impart to it the peculiar, sharp taste of charged water, but should not be developed enough to blow the fluid out of the bottles when the stoppers are removed. Experience shows that 1 to 1½ per cent of sugar will give the correct amount of gas. This may be approximated by adding sugar in the proportion of two even teaspoonfuls of sugar to each pint of milk.

Having the buttermilk and the yeast culture ready, dissolve the sugar in the buttermilk.

(4) Add the yeast culture to the buttermilk in the proportion of one teaspoonful to a quart of buttermilk.

(5) Mix thoroughly and bottle. The bottles should be very strong, as sufficient gas pressure is sometimes generated to break ordinary bottles; the heavy bottles used for ginger ale or other carbonated drinks answer this purpose very well. They should be carefully cleaned and boiled or steamed before filling; fill them full and stopper tightly, wiring or tying the stoppers securely in place.

(6) Place in a cool place to ferment.

If the fermentation is too active, the kefir will have a yeasty taste and the curd is likely to become lumpy and filled with large gas bubbles. A temperature of 18° C. (65° F.) to 21° C. (70° F.) will be found satisfactory for kefir which is to be used on the third or fourth day. The floor of a cool cellar is a convenient place to ferment kefir made in the home. The bottles should be shaken as often as may be necessary to keep the curd in a finely divided condition. The finished product should be smooth and creamy, effervesce rapidly when poured from the bottle, and have the pleasant, acid taste of buttermilk, with the added sharpness caused by the gas and the trace of alcohol. Kefir two or three days old may have a yeasty taste, but if it has been properly made this will disappear as the fermentation of the sugar nears completion; made under these

conditions it should be used when three to five days old, but if put on ice it may be held for a week or even longer.

Kumiss

The missionary monks and other wanderers who first penetrated the undulating, treeless plains of European Russia and central and southwestern Asia brought back descriptions of a fermented drink which in the light of more recent investigations is easily recognized as kumiss. These vast prairies are inhabited by tribes of nomads who live in tents or squalid huts in the winter and wander during the summer, seeking pasture for their horses, their herds of cattle, or flocks of sheep. They are all horsemen, and by a process of selection in which they have probably played only a passive part have developed an exceptionally hardy race of horses. The mares give much more than the ordinary amount of milk, which constitutes almost the entire food of the people during the summer. This is never used in the fresh condition, but is fermented to make kumiss. Unlike kefir, there is no dried "ferment," "seeds," or "grains" with which the fermentation of the mare's milk is started. It is the practice of the natives, when it becomes necessary to establish the fermentation anew, to add to milk some fermenting or decaying matter, such as a piece of flesh, tendon, or vegetable matter. Whatever the material used to supply the essential organisms, it is evident that the milk is so cared for that a combination of an acid and an alcoholic fermentation is favored and the necessary bacteria and yeast are soon established. No doubt the change in the milk is produced under different circumstances by different combinations of bacteria and yeast, and there are usually present various contaminating organisms which are detrimental or at least are not essential to the production of the kumiss. Native kumiss-makers lay great stress on the quality of the milk, the breed of the mares, and the condition of the pastures; but it is probable

that their troubles ascribed to variations in these conditions are more likely attributable to imperfectly controlled bacteriological factors.

There was at one time much interest in kumiss as a therapeutic agent in the treatment of tuberculosis, and sanatoria were established in Russia where invalids could get this treatment. It is probable that the benefits, real or imaginary, derived from it come more from the general methods, which correspond somewhat to present practices, than from the action of kumiss.

Mare's milk is lower in nutritive value than cow's milk, as the following table, taken from Richmond's Dairy Chemistry, shows:

AVERAGE COMPOSITION OF COW'S MILK AND MARE'S MILK

	WATER	FAT	SUGAR	CASEIN	ALBUMIN	ASH
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Cow	87.10	3.90	4.75	3.00	0.40	0.75
Mare	90.06	1.09	6.65	1.89		.31

The composition of kumiss varies somewhat with the age, the rapidity of the fermentation, and the nature and extent of contamination with extraneous organisms. The following analysis is taken from Richmond's Dairy Chemistry (p. 241):

COMPOSITION OF KUMISS MADE FROM MARE'S MILK

	1 DAY OLD	8 DAYS OLD	22 DAYS OLD
	Per cent	*Per cent*	*Per cent*
Water	91.43	92.12	92.07
Alcohol	2.67	2.93	2.98
Lactic acid	.77	1.08	1.27
Sugar	1.63	.50	.23
Casein	.77	.85	.83
Albumin	.25	.27	.24
Albumose	.98	.76	.77
Fat	1.16	1.12	1.30
Ash	.35	.35	.35

It will be observed that this fermentation produces no changes that could be expected to increase appreciably the digestibility of the nitrogenous part of the milk except the possible advantage of a finely divided curd. Mare's milk differs from cow's milk in giving with rennet a softer, more friable curd, but it is not certain that this property would increase the value of kumiss.

Kumiss is often made and offered for sale in this country, but as this is usually made from cow's milk, it is, more correctly, kefir.

Yogurt

In passing to a consideration of the fermented milks used by the people of the countries bordering on the eastern end of the Mediterranean we find a preparation very distinct from that of the Caucasus and the Russian steppes. Kefir and kumiss are limpid, mildly acid, and distinctly alcoholic; but the yogurt, yahourth, or jugurt of the Turks, the kissêlo mlêko of the Balkan people, the mazun of Armenia, the gioddu of Sardinia, the dadhi of India, and the leben or leben raib of Egypt, are all thick-curdled milks, decidedly acid, and with very little or no alcohol. The method of preparation is also quite different. Goat's, buffalo's, or cow's milk may be used. This is usually boiled and sometimes is reduced by evaporation to one-half its original volume. In the latter case it is not used as a drink, but is eaten, frequently with the addition of bread, dates, or other food.

A portion of the previously fermented milk is used to ferment the fresh milk. Unlike kefir, there are no "seeds" through which the fermentation can be transmitted, but the essential organism is sometimes preserved by drying the fermented milk and reducing the dry material to a powder. This constitutes the "podkwassa," or "maya." The organism giving these milks their distinctive character is evidently

identical in them all, or, more properly speaking, may be any one of the several varieties of a distinct and closely related group. On account of its peculiarities, some of which are exceptional and striking, and the importance recently attached to it by the discussions both in the scientific and the popular press, a brief résumé of its characteristics is given:

This bacterium was probably first observed by Kern, who incorrectly designated it *Dispora caucasicum*. His description, however, is so limited that it is impossible to attach the name he proposes to any particular organism. Later Beyerinck, under the name *Bacterium caucasicum*, and Freudenreich, as *Bacillus caucasicus*, described organisms isolated from kefir which agree in their essential features with those obtained from yogurt. More recently Rist and Khoury isolated from Egyptian leben two bacilli to which they gave the names *Strepto-bacillus lebensis* and *Bacillus lebenis*. Grigoroff and Cohendy isolated similar organisms from Bulgarian fermented milk. These various bacteria are undoubtedly nearly or quite identical and all are included under the name *Bacillus bulgaricus*, now generally adopted. More strict adherence to the commonly accepted rules of bacteriological nomenclature would retain the name *Bacterium caucasicum* proposed by Beyerinck. Recent work by Hastings and by Heinemann and Hefferan indicates that this bacterium is not peculiar to the eastern fermented milks, but is widely distributed, having been isolated from milk, soil, saliva, feces, and various soured foods. White and Avery believe that this bacterium is the representative of a group of closely related bacteria which they divide into two types on the basis of their activity in milk and the nature of the lactic acid formed. The characteristics of the typical culture may be summarized as follows:

Morphology. — Slender rods 2 microns to 6 or 8 microns in length, breadth usually about 1 micron, flagella and spores

absent. Long chains frequently occur and apparently vary with different strains and conditions; pseudobranching has been observed. Very long threads without apparent division are frequently observed in old cultures. Living cells are gram positive; dead cells are gram negative.

Growth on artificial media. — One of the most striking features is its inability to grow on ordinary media. It grows on whey, malt, and slowly on whey agar and certain specially prepared media. The colonies on whey agar are masses of tangled threads resembling colonies of the anthrax bacillus. Gelatin is not liquefied.

Relation to oxygen. — Most varieties grow equally well in the presence or absence of oxygen.

Temperature relations. — The maximum temperature is near 45° C. (113° F.). The minimum growth temperature varies with different members of the group, but it is always comparatively high. Most varieties grow very slowly at 25° C. (77° F.), but some grow at 20° C. (68° F.). Hastings and Hammer state that at 20° C. (68° F.) it forms 4 per cent acid in milk as compared with a maximum of 3 per cent at 37° C. (98° F.). According to White and Avery it is killed by an exposure of 15 minutes at 60° C. (140° F.).

Fermentation of sugars. — Many of the sugars are fermented, but statements of different workers are conflicting. It is probable that this property varies in different varieties.

Milk. — The action of this organism on milk distinguishes it from all other known bacteria. At the optimum temperature milk is curdled in a few hours with a rather soft curd, frequently somewhat slimy, which ordinarily does not separate from the whey even on long standing. In twenty-four hours the milk may show acidity equivalent to nearly 2 per cent of lactic acid, and on standing several days this may become about 3 per cent. The most active of the ordinary lactic acid bacteria seldom exceed 1 per cent lactic acid. The more

active type of *Bacterium caucasicum* forms the inactive lactic acid, while the levorotatory acid is produced by the type forming acid more slowly. Small amounts of other organic acids and traces of alcohol are formed.

This bacterium is evidently the essential organism of yogurt, matzoon, ceiddu, leben, and similar fermented milks. Other bacteria are always present, some of them habitually and others only occasionally. Some of these may have an influence on the flavor, while others are inert. It is probable that there are none, with the exception of *Bact. caucasicum,* that cannot be replaced by other species without appreciably affecting the results. Doubtless slightly different varieties of fermented milk have developed in different localities owing to different combinations of bacteria or of bacteria and yeasts. The Egyptian leben is reported to contain alcohol, but not in quantities sufficient to produce an effervescence such as is observed in kefir or kumiss. One of the ordinary lactic acid bacteria seems to be always present with the *Bact. caucasicum,* and it is probable that if it is not essential it is of some assistance in starting the lactic fermentation and, especially if the temperature is low, in suppressing contamination before the *Bact. caucasicum* has time to develop sufficient acid to check extraneous bacteria.

Hastings and Hammer could not detect evidences of proteolytic enzymes by the usual tests, but found in old-milk cultures a distinct peptonization of the casein which was not traceable to the action of the acid. This change is so slow and so small that it cannot be considered as having any influence on the digestibility of the milk. Otherwise, the only changes in the milk constituents are in the conversion of the sugar to lactic acid and very small amounts of volatile acids and traces of alcohol.

"Yogurt buttermilk" is now sold in several cities, and the growing demand will doubtless soon extend its manufacture more generally. In making yogurt in this country better

results are obtained by using with the *Bact. caucasicum* a culture of an ordinary lactic acid organism such as is used in making buttermilk. *Bact. caucasicum* growing alone in milk forms usually a rather slimy, tenacious curd which cannot be broken up into the smooth, creamy condition essential to a good buttermilk. If this organism is grown in combination with the ordinary lactic acid organism, a more friable curd is obtained, and the sliminess is not so evident. The two organisms can be carried in mixed culture only with great difficulty, as the high acid soon suppresses the ordinary form. The most satisfactory results can be obtained by making buttermilk in the ordinary way and churning it with an equal quantity of milk curdled with the yogurt organism. This procedure gives the desirable texture of buttermilk and a distinctive flavor.

If a culture can be obtained, yogurt can be made in the home. If a reasonably active dry or fluid culture can be obtained, the following procedure should be satisfactory:

(1) Heat one-half pint of milk in a double boiler, holding it one-half hour after the water begins to boil.

(2) Cool this milk to about 100° F. (about blood heat). At this temperature the container will feel warm, but not hot, to the touch.

(3) Add a considerable quantity of the culture to this milk. If it is in the form of tablets, three or four should be used.

(4) Transfer the milk to a bottle or fruit-jar — or, better still, a vacuum-insulated bottle — which has been rinsed with boiling water, and keep overnight in a warm place. Good results may be obtained by placing the bottle or jar, containing the milk, in a dish of water warmed to about 100° F. The most favorable temperature for the fermentation is at or a little below blood heat. At a little higher temperature the organism grows faster, but the curd is likely to separate from the whey as a tough mass. At a lower temperature the growth may be so slow that other bacteria gain the ascendency. By

the following morning the milk should be curdled with a thick, somewhat stringy curd with a sharp, acid taste.

(5) Heat 1 pint to 1 quart of milk as in (1), cool and add 1 teaspoonful of the curdled milk obtained in (4).

Hold this milk as before, and when it has curdled break up the curd by shaking vigorously in a fruit-jar.

This process may be repeated so long as the curdled milk has a smooth, acid curd free from undesirable flavors and particularly the yeasty flavor and odor characteristic of bread dough. The so-called *Bacillus bulgaricus*, under favorable circumstances, will suppress other bacteria by its vigorous acid formation, but yeasts are favored by the acid condition of the milk and sooner or later make their appearance. Every precaution should be taken to protect the milk from exposure to the air and to sterilize all utensils with boiling water. When evidences of yeast contamination appear, it is best to start with a fresh culture.

Yogurt may be made more palatable by adding to two parts of the yogurt one part of cold water, or, better still, cold-charged water, which can be bought in siphons at drug stores. Sugar and lemon juice or other fruit flavor, or chocolate sirup, may also be used for this purpose. The sugar should be added in the form of a sirup, as granulated sugar dissolves very slowly in the cold yogurt.

In making yogurt on a large scale the process is not essentially different except that it is advisable to carry a small culture, about 1 quart, to inoculate the milk to be made into buttermilk. Every precaution should be taken to maintain the purity of the culture. It is advisable to carry duplicate cultures independently so that a good one will always be available.

Expensive outfits for making fermented milks are on the market, but while they may be convenient they are by no means essential. For the smaller dairy the following procedure will probably be found satisfactory:

(1) Propagate a small culture from day to day as indicated in the directions given above.

(2) Carry in a similar way a culture of the ordinary sour-milk organism, which may be obtained from many of the commercial laboratories.

(3) Thoroughly pasteurize the milk to be fermented. If a small quantity — 5 to 10 gallons, for instance — is to be made, it may be done by holding a can of milk in a tub or vat of water heated by a steam hose. If a larger quantity is made, one of the starter cans used in creameries will be found convenient. These are essentially cylindrical vats with mechanical stirrers and a jacket which can be filled with steam for heating or water for cooling. The milk should be held at a temperature of at least 180° F. for not less than thirty minutes.

(4) Cool the milk to about 100° F. Draw off one-half and inoculate it with the culture obtained in (2). Inoculate the remaining half with the bulgaricus culture obtained in (1). The amount to be added will depend on the quantity of milk to be fermented, the time at which it is desired to have it curdled, and the temperature maintained during the fermentation. This can best be determined by experience. One pint should be sufficient for any amount between 10 and 20 gallons.

(5) The milk inoculated with (2) may be held at ordinary room temperature. Precautions must be taken to hold that part inoculated with the bulgaricus culture at a temperature of 90° to 100° F. for several hours. If the milk is in cans, it may be set in a tub of warm water. A large volume of milk in a warm room will maintain the proper temperature.

If one is unable to hold the milk at the desired temperature, the amount of culture inoculation should be increased.

(6) When the milk has curdled, which should be in ten or twelve hours, mix the two lots thoroughly by churning or stirring together, bottle, and put on ice to check the acid formation.

CHAPTER XIV

ICE CREAM MAKING

THE term ice cream as at present used is a broad one, including a great variety of frozen products. In the past few years the demand for ice cream in this country has increased with great rapidity. While formerly it was considered as a luxury to be used only on special occasions, it has come to be a necessary daily food, and its manufacture now represents one of the important branches of the dairy industry. The manufacture of ice cream has not been sufficiently standardized to give a well-defined definition or a standard classification of the various frozen products, but the following definitions are given by the United States Pure Food Law:

1. Ice cream is a frozen product made from cream and sugar with or without a natural flavoring, and containing not less than 14 per cent of milk-fat.
2. Fruit ice cream is a frozen product made from cream, sugar, and sound, clean mature fruits, and contains not less than 12 per cent of milk-fat.
3. Nut ice cream is a frozen product made from cream, sugar, and sound, non-rancid nuts, and contains not less than 12 per cent of milk-fat.

Mortensen [1] has proposed a classification, dividing the frozen products into the following general classes:

1. Plain ice cream.	3. Fruit ice cream.
2. Nut ice cream.	4. Bisque ice cream.

[1] Iowa Bulletin No. 123.

5. Parfait ice cream.
6. Mousse ice cream.
7. Pudding ice cream.
8. Aufait ice cream.
9. Lacto ice cream.
10. Ices, including sherbets of various kinds.

ESSENTIAL CHARACTERISTICS OF ICE CREAM (adapted from Washburn[1])

Flavor.

Ice cream is eaten primarily as a luxury rather than as a food. Not that the food value of ice cream is non-existent; far from it. It is a most desirable form of food; but it is not likely to be chosen for its food value, but on account of its pleasure-giving properties. Of these, flavor is probably the most important; hence the necessity of its close supervision.

Naturally the amount and quality of the flavoring material or extract have a marked effect upon the character of the finished product. Choices in this respect of course are dictated by market demands and individual preferences and do not properly form any part of this discussion.

The fat-content of the cream decidedly influences the flavor. A rich cream possesses a better flavor than does a lean cream, other things being equal. Above everything else the cream should be as free as possible from all contaminations.

Cream used in ice cream making should contain not more than 0.25 per cent acidity, and 0.16 to 0.18 per cent is to be preferred. As it approaches 0.30 per cent acidity the sour taste becomes apparent and proportionately unpleasant. However, cream which is almost sour enough to churn may be used if it is mixed with five to ten times its volume of sweet cream, or if it is neutralized in part by the use of baking soda or of viscogen (sucrate of lime). If either is used in excess, however, the cream becomes alkaline and the product has a bitter flavor.

Salt is not usually added to ice cream, purposely at least;

[1] Vt. Bul. 155.

but careful and repeated tastings by many persons proved that the unbiased consumer prefers a cream containing salt at the rate of half a teaspoonful to a gallon of mixture to a cream which is not thus modified. The taste of the salt as such does not become evident until a much larger quantity is used. However, although the addition of a small quantity tends to deepen and to enrich the flavor of ice cream, it should be used with care, if regularly at all, for the reason that even a slight excess does much damage.

Ice cream is not at its best until it has stood from twelve to twenty-four hours to ripen. This term, "to ripen," as used in this connection is meant to cover the commingling, the blending together of all of the many flavors naturally present in or artificially added to the product. When freshly made, each separate flavor may be distinguished and singled out. But after having stood for twenty-four hours, all of these flavors tend to blend to a considerable degree into a single flavor, the value of which depends on the quality of the several ingredients used.

Body.

The words "body" and "texture" are used in ice cream making to mean two quite definite things. "Body" is synonymous with structure or substance. It refers to the entire mass as the unit. "Texture," on the other hand, has to do with the finer make-up of the article.

A firm, mellow, but not hard or rubbery, body is a feature to be sought in ice cream work. Milk solids are the best body-giving materials used. When in plentiful amounts the general firmness of the finished article is assured; but when scanty, its body becomes weak and mushy, unless otherwise reenforced. A 25 per cent cream affords an excellent body. An 18 per cent cream should be deemed the minimum, for its product will begin to betray weakness. A cream testing 22 per cent fat before the sugar is added will meet most requirements of regular work, so far as quality (body) is concerned.

Aging a cream tends to better the body of the product. Preferably a cream should not be used until it is twenty-four hours old as cream, or is even two days old; and if it is held cold (32° to 35° F.) during this time, so much the better. The same cream which, when used within four hours after separation, produces a weak, slushy-bodied article, may, when held at 32° to 35° for twelve or more hours, produce a firm piece of goods. This change is held by some to be due to the rearrangement of the molecules of fat within the fat globule.

Pasteurized cream makes a weak, slushy, and inferior article, unless it has been held cold for twelve hours or more, when it may yield a thoroughly satisfactory product. But twelve hours' aging is not its only need; it must have been kept cold for the six hours immediately preceding its use, if the best body and swell are to be secured.

Fillers. — When it is difficult or impossible to control the condition of the cream which is being used, a small investment made in unsweetened evaporated milk will produce far more and better body than will an equal sum expended directly for butter-fat. Gelatin, also, tends to produce a more satisfactory body. In fact a mature, tempered ice cream which contains no gelatinoid binder is weak and will yield easily to slight pressure, whereas the same cream "mix," made up with gelatin, offers more resistance at any usual temperature of holding and is found to be very slightly elastic under the touch. Wheat or rice flour, or corn starch are not infrequently used in lean creams. They are not needed in rich creams. Naturally the more such materials are used, the more like a pudding and the less like an ice cream the goods become and the firmer will be its body.

Texture.

A smooth, velvety texture is desired in ice cream rather than a coarse-grained mass of crystals. Milk-fat is an excellent agent in the production of a smooth cream; the richer it is,

other things being equal, the smoother the product, whereas, the leaner the cream, the coarser and more spiny is the finished product. However, full more important is the manner of freezing, which has much to do with success. If the mass is frozen too rapidly, it will be coarse and full of large water crystals, while if it is frozen more slowly the tendency is to improve its smoothness. This outcome is not so much due to the rate of freezing as to the amount of whipping or beating which ensues while it is freezing. If it is frozen without any agitation whatsoever, the product will he extremely coarse, even unpalatable, in fact thoroughly worthless as commercial ice cream, even though made from a rich cream, one containing say 25 per cent fat; whereas had it been thoroughly whipped during the freezing process, enough air would have been beaten into it to have produced a light, smooth, cushiony consistency and a fine, palatable, merchantable article, even though a somewhat thin cream were used. In properly made ice cream, the water freezes in very fine crystals which are thoroughly interspersed with minute bubbles of air. When the volume of an ice cream includes 33 to 40 per cent air, the product is more velvety in texture, more pleasing to the palate and richer to the taste, than is one containing no air. Cream fresh from the separator or pasteurizer produces a coarse-grained ice cream, whereas if kept cold (32–35°) for twelve hours, it makes a smooth cream. In order that its texture may remain fine for any considerable length of time, as is necessary in commercial work, it seems to be essential that some gelatinoid binder (such as gelatin, or one of the gums) be used, for when an ice cream which contains no gelatinoid has been hardened and held for a day or two, the water crystals grow, forming sharp spines. This unpleasant change continues to increase in extent for some days and often makes the product very unsatisfactory. Ice creams, on the other hand, which contain a gelatinoid binder remain smooth much longer and grow coarse much less rapidly.

Swell.

The overrun, or the amount (volume) of ice cream obtained in excess of the amount (volume) of total mixture put into the freezer, constitutes the "swell." This increase in volume is due almost wholly to the incorporation of air into the product and, to a very slight degree indeed, to the expansion of the cream due to freezing. The amount of swell obtained is a sort of component resulting from several coöperating factors.

A *viscous cream* retains more of the air which is whipped into it than does a cream relatively non-viscid; hence the more viscid it is, the greater the swell, other things being equal. The viscosity of a cream increases very noticeably from the hour of its separation or pasteurization for about six hours, and slowly thereafter for several days, especially if it is held cold. The cause for this increased viscosity is but poorly understood, but it seems to be due to a slight thickening not unlike the clotting of blood.

The *rate of freezing* is an important factor in this matter of increase in volume; for the reason that if the freezing be done too rapidly, too little time elapses to admit of its thorough whipping or beating, during the interval after the cream becomes cold enough to whip and before it becomes frozen. In other words, the temperature drop through the few critical degrees of cream whipping is too rapid to admit of a thorough incorporation of the air. The ordinary mixture of cream and sugar used in ice cream making is too thin and sloppy to retain any appreciable amount of the air whipped or beaten into it before it reaches about 34° F. At this temperature it begins slowly to foam up and gradually increases in volume until the temperature of 29° to 28° is reached, at which point (its true freezing point, which varies from 29° to 28°, depending on the amount of sugar in the solution, and in general practice, too, on the accuracy of the thermometer used) the temperature ceases to drop and stands for some minutes without becoming any colder, as

measured by the thermometer, nor changing its apparent condition. This stationary condition of the mix, in practice with batch machines, will continue for four to fifteen minutes, depending on the rate of the freezing. It is during this time that the latent heat is being extracted from the cream and transferred into the ice, melting it. The swell, though beginning at about 34°, is by far the most rapid near the end of this apparently inactive period. In fact just before the material fully freezes, the increase is surprisingly rapid. At about this time the temperature drops to 27° and the cream becomes brittle and ceases swelling altogether. At 28° to 27° the product is ready to remove from the freezer.

Now, the rate at which cream cools depends on several factors, chief among which are: the temperature and rate of flow of brine (brine freezer), or the amount, proportion, and size of salt and ice (ice freezer); the relation of the mass of these to the mass of cream being cooled; the surface exposed for cooling action; and, finally, the difference in temperature between the cream and the freezing agent.

For example, 10 pounds of ice, 1 pound of salt, and 1 quart of water produce a brine of about 21° in temperature. This, acting upon 6 pounds of mix at a temperature of 70°, cooled it about 20° the first minute and 10° the second minute, yet slowed down continually so that it required a full minute to lower the temperature from 30° to 29°. So far as the swell is concerned, however, it practically all takes place during the time, be it ten minutes or twenty, in which the cream is dropping through the successive Fahrenheit temperatures from 34° to the end of the 29° period.

The maximum of swell is reached at the point of thorough freezing (about 28½° F.); but if the ice cream is drawn or dipped away at this critical point the warmth of the air and the tools tends to melt it somewhat, especially where it lies against the walls of the holding can. When this melted matter again

freezes, coarse spines or crystals will be produced. The moment it freezes thoroughly it becomes brittle and, instead of holding more air, it slowly gives up that which it has already taken on, or, in other words, it "beats down"; hence the colder the cream is made before its removal from the freezer, assuming a uniform rate of speed for the dasher, the smaller will be the yield. The best temperature for withdrawal seemed to be 28°, even though at this temperature the product was thin enough to pour like heavy gravy or condensed milk. Those creams with which the greatest swell was obtained required the longest time to cool through to the 17° or 16° of holding temperature. The cream does not swell at first, unless it is put into the freezer at not above 34° in temperature. Hence it is folly to run at a high rate of speed at the outset, and may even cause damage by partially churning the cream before it cools to a point below the churning temperature. When the speed is controllable, a slow initial movement followed by a rapid one when the cream reaches the whipable point, and, finally, a speed slowed down to prevent loss of swell while finishing off or carrying the cream from 29° to 28°, or from 28° to 27°, seems to be the best procedure. If this can be done carefully enough it may be hardened to 26° before removing from the freezer.

The amount of fat in the cream has little or nothing to do with the amount of air which may be incorporated; but it has much to do with the amount which remains incorporated. A skim-milk can be made to swell 100 per cent or even more; but the product is coarse and the result only a temporary one, for it quickly loses its air and falls or sinks in the can.

In order to whip well and to remain whipped, a cream should contain from 18 to 22 per cent fat, should be twenty-four hours old as cream, and should be cold. A cream containing 35 to 40 per cent is too soggy to whip well and affords only a poor increase. The per cent of swell obtained is based on the amount of "mix," and not simply on the amount of cream before sugar is

added. The aim should be to obtain not less than 50 per cent, and seldom more than 70 per cent, of increase. A swell of 80 per cent or more is usually obtained at the expense of body. Ice cream must not be too fluffy, or it will fall or sink upon standing, and neither consumer nor producer will be satisfied.

It is a fact that an ice cream the volume of which is approximately a third air is more satisfactory to the consumer than is one containing no air. It has a more velvety feel on the tongue, and conveys a sensation of richness without causing the unpleasant effects of an excessively rich cream, in the same way that a whipped cream or a well-beaten egg seems richer than does the same article in its natural state. Furthermore, the presence of air in a finely divided form causes the whole mass to be in fact partially insulated against heat conduction, so that an ice cream containing air "stands up" better both in the mouth and on the plate, than would the same cream if no air had been incorporated, and further, the whipped ice cream will chill the mouth and stomach of the consumer far less than that made without air. A demand that ice cream be served entirely devoid of air is no more reasonable than would be a requirement that a loaf of bread be held down to or compressed into the least possible volume. They both need to be light in order to attain the highest palatability.

THE CONSTITUENTS OF ICE CREAM (adapted from Washburn)

The cream

Flavor.

The flavor of the cream to be used in ice cream making is an important matter. Special attention should be given to its selection and handling. Not only should it be free from the food taints occasionally introduced by the cow, and free from that "cowy" flavor which usually means merely manure flavor, but it should also be devoid of those dirty dish-water flavors not

infrequently picked up at the points of ice cream manufacture. Hot water and human labor are both expensive; yet both are essential to cleanliness. It is entirely probable that some, at least, of the apparent cases of ptomaine poisoning ascribed to old re-frozen ice cream were due to the action of putrefactive organisms introduced by the stale, greasy, and half cold water used in washing the cans. To those who know milk and its handling, there is no flavor more disgusting. A cream which has started to sour may under stress be used, either by the use of sweet cream or by first reducing its acidity to that of normal cream, say to about 0.20 per cent acid, using either bicarbonate of soda (baking soda, saleratus), or viscogen (sucrate of lime).[1] Care must be taken, however, not to add too much, lest the cream be made alkaline and the taste bitter.

Fat-content.

Ice creams, or ice milks, as the case might be, were made, using varying grades of material testing 43 per cent, 37 per cent, 30 per cent, 25 per cent, 22 per cent, 18 per cent, 12 per cent (cream), 8 per cent, 4 per cent (milk), and 0 per cent (skim-milk). The rich 43 per cent cream afforded a poor yield, swelling but little. It had a firm body, but was so buttery and rich in flavor that it did not approve itself to a single one of the several dozen tasters, whose verdicts in this and other trials mentioned all through this bulletin were always given in entire ignorance of the identities of the creams they were sampling. The 37 per cent and the 30 per cent creams met with somewhat more favor and gave better results; but they were still too rich. The cream testing 25 per cent fat (before the sugar was added) was the choice where the swell was very moderate; but when the several lots were frozen slowly and thoroughly whipped, the consequent incorporation of air so increased the apparent richness of the cream that the 22 per cent goods was largely

[1] Wis. Sta. Bul. 41 (1894).

preferred to that made with the 25 per cent cream. All of these had good body. Upon reaching the lot made from 18 per cent cream, a weakness of the body was very apparent and the spiny condition due to water crystals began to appear. The 12 per cent goods were very weak; and everything made from milk or skim-milk was what might be termed coarse, spiny slush. An 18 per cent fat-content should be considered the minimum when making plain ice cream.

Age.

Without endeavoring to enter on the causes which underlie the change brought about by aging cream, which is at best but poorly understood at present, it is a fact that cream and milk do in small measure clot upon standing, in somewhat the same manner as does blood; that milk is more viscid after some hours of standing than when freshly drawn, even at the same temperature (the acidity remaining the same), and considerably more viscid after having been held cold for twenty-four hours. Cream likewise possesses a greater viscosity if it is held for at least six and preferably for twenty-four hours before it is used in making ice cream. This is especially the case if it is held cold in the interim.

Holding temperature.

Inasmuch as increased viscosity favors an increase in yield, it follows that cream intended for ice cream making should be held at a point close above freezing. This is for several reasons: At this temperature it remains sweet and usable longer than if held warmer; its viscosity is increased, thus favoring the production of a good and uniform swell in the finished article; and, because of the thorough hardening of the butter-fat which the prolonged chill induces, a better body is attained. It is well known to butter-makers that the butter-fat in the cream needs several hours of thorough chilling prior to churning, if good body and grain are to be attained; that butter made from cream churned immediately after cooling will be much softer in body

than the same butter would have been had the cream remained cold for some six hours immediately prior to churning. The same law holds true in ice cream making. A better bodied goods may be made when the fat has been cooled for a sufficient length of time to allow thorough hardening. The most economical and efficient method of holding or cooling milk or cream with ice is to set the filled cans into a well-insulated tank of water in which the ice is floating. In this way the maximum of cooling effect is obtained from the ice, and the cream or milk is cooled much more quickly than would be the case if it were set into a room, even though the air were of the same temperature as the water. Furthermore, this pre-cooling of the cream enables the maker to freeze his goods in a short space of time without cooling it too rapidly (see p. 537). This feature is especially valuable where several batches must be run through the same freezer in quick succession. It also has the final advantage of practically guaranteeing that no crumbs of butter will be formed in the freezer, for all of the agitation of the cream will have taken place at a temperature far below the churning point.

Keeping cream sweet.

A can of cream or milk set into cold water will cool many times more rapidly than it will if set into a dry air refrigerator, even though the air and water were kept at the same temperature. This is due to the fact that water is a much better conductor of heat than is air and that the heat-carrying capacity of the mass which is able to come into contact with the can is immensely greater in the case of water; in fact the amount of heat required to be absorbed from the article being cooled in order to raise the temperature of water one degree is 445 times greater than the amount of heat required to raise the temperature of the same volume of air one degree. Or, in other words, one cubic foot of water will absorb 445 times as much heat from the can of cream as will one cubic foot of air for each

degree rise in temperature. And added to these facts is another equally as important, namely, that it is next to impossible to cool the air of a refrigerator with ice much below 50°, while the common temperature is about 55°, which must be looked upon as merely the lower limit of normal souring, at which the growth of lactic acid bacteria will be slow but certain. On the other hand, the temperature of water in which a few large chunks of ice are floating will be found to range from 34° to 38°. Thus cream set away to mature, yet to keep sweet, will not only cool much faster but also to a lower point if water is employed. This system, when a well-insulated tank is used, is not only the most efficient, for the reasons just given, but also the most economical of ice for the reason that practically all of the cooling power of the ice (that is, both the latent and the specific cold, if one may use the reversal term, which, though perhaps coined, serves admirably the present need), will be employed for useful purposes instead of being largely wasted, as is the case when the cans of cream are merely packed close in a corner and buried with broken ice. When this is done, as is so often the case, the can is largely surrounded merely by cool air, and the ice cold water formed by the melting ice runs away to the sewer, still capable, however, of having done much good, quick work.

Acidity.

The acidity of the cream has no effect on the swell of the ice cream produced, until it reaches such a point as to cause the cream to become brittle, when a lessened yield will result. It becomes sour to the taste and smell long before the yield will be affected. Either natural, or added commercial, lactic acid seems to improve the body and texture slightly. A cream containing 0.50 per cent or even 0.60 per cent acid will make a good looking and good feeling ice cream, and, except for the sour taste, will be as satisfactory an article as could be desired. The sour flavor, however, will be detected if the cream possesses more than 0.26 per cent or 0.27 per cent of acid, and it is un-

palatable to most consumers if it contains more than 0.30 per cent to 0.32 per cent. Cream of this quality may occasionally be used, especially if partially neutralized and then mixed with some sweet cream and frozen for immediate consumption, or if it is mixed in small amounts with sweet cream.

Pasteurized cream.

The pasteurization of sweet cream improves its keeping qualities and general market value; but it decreases its apparent value and causes it to seem to be of less value than it really is, because of the lowered viscosity resulting from the employment of the process. This peculiar and well-recognized effect is apparently due to the impairment of the clustering together tendency of the fat globules. The process in no wise affects the food value of the cream and it enhances its service for many purposes; but it decidedly affects its appearance. Viscogen (sucrate of lime) has been used to reëstablish the viscosity of pasteurized cream.[1] While it is effective to this end, it is not a sufficiently active agent to warrant its regular use in ice cream making, for the reason that the lapse of time and the employment of a low temperature bring about in pasteurized cream an essential return of its original viscosity. If pasteurized cream was allowed to stand cold for twenty-four hours after pasteurization, it yielded as large a volume of as good bodied an ice cream as was that produced by the raw check lot, kept under similar temperature conditions for the same length of time. Hence pasteurized cream may be freely and successfully used in ice cream making, if it is allowed time to reëstablish its viscosity.

Homogenized cream.

A homogenized cream is one which has been made homogeneous or identical throughout its entire mass by having been passed through a special apparatus which, under pressure of

[1] Its use is illegal in several states and is to be decried under all circumstances unless its presence is declared to the consumer.

from 3000 to 5000 pounds to the square inch, so breaks up the fat globules in the milk or cream as almost absolutely to prevent all cream from rising. It also makes it extremely difficult or impossible to do thorough skimming even by centrifugal force; neither may the cream be churned. But its viscosity is greatly increased, a change in character which obviously lends itself particularly well to ice cream making.

This process enables the ice cream maker to use a cream carrying from 16 to 17 per cent fat, and to secure in his final product a body and texture fully equal to that produced by the ordinary unhomogenized 22 per cent and 25 per cent creams. If homogenized cream is used alone, the results are often disappointing. If, however, $\frac{4}{5}$ to $\frac{9}{10}$ of the total quantity of cream used is homogenized, while the remaining portion consists of normal rich, raw cream, the results are almost sure to be satisfactory. The addition of even a small quantity of a cold twenty-four hour old milk to homogenized cream materially improves its ice cream making qualities. Cream homogenized at about 175° possesses a peculiar clinging flavor, resembling that of starch. This peculiar effect impairs the eating quality of the product, unless it is allowed time in which to overcome it. This recovery is secured in a couple of days, whether the homogenized and pasteurized product is held cold as cream or is made up into ice cream and then held. Moreover, the evidence thus far obtained seems to indicate that no condensed milk is needed to produce body when homogenized cream is used; in fact the addition of only a single quart of condensed milk to 10 gallons of 16 per cent homogenized cream made an article possessing too much body. Ice cream made of 9 gallons of homogenized cream testing 16 per cent fat, and 1 gallon of plain 18 per cent cream, with sugar and flavor, proved superior in body, texture and in general creaminess to that ordinarily produced with 10 gallons of 18 per cent cream and 2 quarts of condensed milk, both containing gelatin in equal proportions.

Condensed milk.

Condensed or evaporated milk is frequently used in ice cream making; and provided wholesome goods are used in not immoderate quantities it has a legitimate place therein. It increases the body and smoothness of the goods, without producing that extreme richness in fat which would be required of a normal cream to secure the same quality effect. Many ice cream makers may find it to their advantage to purchase quantities of the evaporated milk which has been partially churned in the "breaking" process at the condensory. This milk is in every respect as pure and wholesome as is any condensed milk, but on account of these minute granules of butter is not sold on the open market. By pouring the evaporated milk through a sieve the granules will be removed, the loss will be insignificant and the main product will be as valuable as though a higher price had been paid for it. Better yet, where the ice cream maker has access to a homogenizer the cans of partially churned or clotty condensed milk may be emptied and the contents run through the machine at a temperature of 170° to 180° with the effect of restoring to the article much or all of the qualities possessed by the normal and high priced goods. It goes without saying, however, that the so-called "swells," *i.e.* goods faulty because of fermentation within the can, cannot be thus used; and the semi-decomposed barrel goods, sometimes offered the trade, are also tabooed. Either may be a fruitful source of ptomaines. The use of such materials emphasizes the importance of thorough survey of each and every ingredient used in the making of ice cream and the real inefficiency of any examination solely of the finished product. Unquestionably the occasional use of such stuff has had much to do with the unfavorable attitude of some food control officials towards the use of condensed milk as an ingredient of ice cream.

The sugar

Ordinarily cream is sweetened to taste when about one-sixth of its weight of sugar is added, making the finished product approximately 14 per cent sugar.

The addition of the usual quantity of sugar increases the volume of the cream between 9 per cent and 10 per cent. Sugar, used in the quantities ordinarily employed in ice cream making, acts as a slight preservative of the cream. At ordinary room temperatures a cream carrying the usual amount of sugar will remain sweet approximately one day longer than will the same cream unsweetened. However, sugar is not present in a quantity which is sufficient to preserve the milk indefinitely; and it becomes sour and otherwise offensive very rapidly when once it starts on its downward career.

Maple sugar is rather soft, and when added to cream settles into compact close masses and dissolves very much more slowly than does the common granulated variety.

The fillers

Starchy fillers.

Wheat and rice flours and corn starch are still occasionally employed to give greater resistance to the body of a piece of goods made from cream low in butter fat. A rich cream does not need a filler; and it is a moot question whether a frozen substance carrying any appreciable quantity of such body-giving material should be considered a true ice cream. It approaches a pudding in character and should be so called. Any one of these materials may be used for this purpose, though wheat flour is to be preferred to corn starch. Apparently because of the gluten thus introduced, the viscosity of the mixture is not materially lessened by the use of wheat flour. Rice flour seems still to meet with more favor, however, because of the fact that rice starch grains are much smaller than most others. Any of

these fillers should be thoroughly cooked before being introduced into the cream, first being made into a very thin paste and then worked up into a greater and yet greater volume of cream, while hot. If not cooked prior to use, the starch grains are very much in evidence when the product is eaten, seeming like rough granules on the tongue. These materials added in too great quantity cause the mixture to become too heavy, in fact so soggy that a fair swell is difficult to obtain. Fillers never increase the swell and if used in excessive quantities lessen it.

Egg fillers.

Eggs are not infrequently used, especially with the fancy ice creams, the so-called French or Neapolitan types. Unless the eggs are cooked, however, the increase of body or of smoothness is scarcely perceptible, unless the goods made are extremely thick with eggs. When cooked, however, into what is virtually a custard and then frozen, a greater body and smoothness is secured, together with a decided loss of volume. Eggs are seldom used in the plain goods and practically never in the cheaper grades.

Rennet fillers.

This well-known substance in some form and usually under some disguising name is not infrequently employed to give a greater body and smoother texture to lean creams. No larger quantity of ice cream can be obtained by the use of rennet, but if the cream is allowed to remain warm long enough for the rennet to coagulate the mass, and it is then cooled for a period and frozen, its body will be slightly firmer and its texture somewhat smoother than would otherwise have been the case. Rennet is the active principle found in some of the ice cream powders, especially those which require introduction into and thorough mixing with the cream for some considerable time before freezing. It has a very small place, if any, in commercial ice cream making.

The binders

Gelatin.

Gelatin is a substance of animal origin. It is the water extractive of bones, and the like, practically identical in character with the jelly-like mass which the cook expects to find in the pot after a soup bone has been boiled. Gelatin is prepared for use by first dissolving it in hot water, or, better yet, in a portion of the skim-milk with which the over-rich cream is reduced. When this has been heated and stirred until entirely free from small lumps or clots of undissolved gelatin, it is quickly strained into the batch of cream while hot and well stirred. A good and quick way to prepare this binder on a large scale is to put it into a milk-can or pail with small top, to add the desired amount of skim-milk, and then to insert a hose or steam pipe and turn in live steam, stirring actively.

Gelatin has been used in commercial ice cream for a great many years and is still being used for the purpose of preventing the water, which is normally and naturally present to the amount of about 60 per cent to 70 per cent of the total weight of ice cream, from forming into disagreeable, spiny crystals when the goods have to be held for one or more days. When ice cream is freshly made, only the veteran ice cream maker whose taste is trained can distinguish that in which gelatin has been used from that made without gelatin; but after the product has been packed for twenty-four hours, that from which the binder was omitted will be found to have a coarse texture while that made with gelatin remains fairly smooth and agreeable. This difference continues to exist and, indeed, becomes greater with the lapse of time.

This substance is not in favor in many states, though its use in ice cream is allowed by the laws of Vermont. Controversy is still being waged as to the advisability of its use. Some maintain that the possibilities of its contamination during the process of manufacture are so great that gelatin is not a safe

or fit substance to be used in ice cream making. Others deny the justice of this attitude and say that if such is the case, its use as gelatin on the table should likewise be forbidden. The fact remains, however, that practically everything which can be said against the use of gelatin from the standpoint of uncleanliness can with almost equal force be urged against milk and cream themselves. It is occasionally contended further, that glue is used instead of gelatin in ice cream making. Even if this be true, it of itself does not furnish warrant for the exclusion of all gelatin, including that pure enough for family table use. The characteristic odor of glue is largely that produced by the decomposition or rotting of the animal matter from which glue is later made, and its use in any food product whatsoever should be most heartily condemned. However, the fact that the clean and higher priced goods are in reality the cheaper to use, will act as a constant and almost automatic regulator in the matter of gelatin usage. From 3½ to 4 lb. of the higher grade, costing about a dollar, will accomplish as much as will 6 or 8 lb. of the cheaper goods costing half as much again. The presence of gelatin does not appreciably affect the amount of the swell unless used in very considerable excess of any amount which the consumer would accept, when a smaller swell is secured.

Gum tragacanth.

Gum tragacanth is a material of vegetable origin and is very similar in its nature to the gum that oozes out of and hardens on the trunks of cherry and peach trees. It does not go into true solution in water. It is used in practically the same manner as is gelatin and for the same purpose. It possesses some advantages over gelatin, especially in being odorless. It seems, too, to be used by those who wish to be able to declare that their goods contain no gelatin. An exceedingly small quantity is sufficient to prevent the formation of coarse crystals. One ounce in chip or shaving form, when soaked and heated in a quart of water, will cause the entire mass to become very heavy and tenacious.

If to this mass one and one-half quarts (three lb.) of sugar is added, about one and one-half quarts of gum tragacanth stock will be produced. Four tablespoonfuls of this stock is enough to use in one gallon, one quart in ten gallons of ice cream. If this amount of sugar is employed, the gum stock will remain usable for several weeks; in fact the amount of sugar used is almost enough to prevent the stock from spoiling at all. Gum tragacanth seems to be gaining in favor, either as such or in the form of some of the many powders that are on the market.

Ice cream powders.

Ice cream powders are being sold under a great variety of names, each implying that a special, creamy, velvety, rich product will inevitably be made as the result of its use. The active principle in most of the powders on the market is either gelatin, gum tragacanth, or a mixture of the two, very finely pulverized and thoroughly triturated with from six to ten times its weight of powdered sugar. Rice flour, dry rennet, and corn starch are also occasionally added to the mixture. Naturally these powders produce essentially the same effect as would the raw materials from which they are built; for catchy trade names are valueless in this respect. Their chief advantage lies in the convenience attending their use, which precludes the necessity of a previous preparation of the stock and of its holding. When these powders are used, they are dusted on top of the mixture after it is placed in the freezer and well mixed. Because of their exceedingly finely divided condition, they spread quickly and evenly throughout the mass.

TYPES OF FREEZERS

The many kinds of freezers on the market may be roughly divided into four classes or types. There are, however, several variants in each class.

Vertical-batch-ice.

This type is the most common of all, being represented by the ordinary upright batch freezer, the kind that has been used for many years. With this type the cream is placed in a large can provided with a dasher and is set, perferably before filling, into the wooden tub. The whole is then put into position and attached and the space surrounding the freezing can is filled with crushed ice and salt. A ten-gallon freezer will require for its first batch approximately 60 to 70 lb. of ice and from 5 to 6 lb. of salt. Following batches may be run with less fresh material, due to the fact that the machine is now cold and provided with considerable ice not yet melted.

Vertical-batch-brine.

The distinctive feature of this freezer is that though vertically placed it is high enough above the floor so that the finished ice cream is drawn from the bottom without stopping the dash. In place of a heavy wooden tub and ice, the freezer proper is surrounded by brine. The rate of freezing in this as in other brine freezers is controlled by the temperature of the brine and the rate of its flow through the machine.

Horizontal-batch-brine.

This type of freezer is quite similar in some respects to the one previously described, the chief difference being that it lies horizontally or nearly so. It is surrounded by brine, the finished ice cream being drawn from the lower side of the lower end. This also usually has a small tank immediately over it or close at one side, in which the next succeeding batch is prepared during the progress of the freezing process. This, like the preceding one, though not a continuous machine, may be worked almost continuously.

Horizontal-continuous-brine.

The evolution of this machine marked a distinct breaking away from the older conceptions of ice cream freezer requirements. In this mechanism the cream flows in at one end of

the machine, and the finished ice cream out at the other. The freezing is done by the passage of brine through the disks which revolve rapidly in the cream as it is being crowded to flow from one end of the machine to the other. This type of machine is open and in some respects offers advantages not possessed by the closed machines, especially in giving the operator opportunity to use the thermometer more accurately in the freezing process, which is a distinct advantage. This type of machine is made in different sizes with both single and double sets of disks.

It should probably here also be noted that the use of a brine freezer is not restricted to the plants having artificial refrigeration. The brine for circulation through disks or around the freezer may be provided either from the large brine tank of the artificial cold storage system, or may be produced at will by the mixing of salt, ice, and some water in the brine box which accompanies the machine if desired. This brine is then forced by a small pump to circulate and do the work of freezing.

THE FREEZING PROCESS

The freezing mixture almost universally used consists simply of common salt and ice. Salt is deliquescent, that is to say, has an affinity for water and attacks the ice to procure the water for which it craves. However, any change of any body from the solid to the liquid state, no matter what the body is, is accomplished only by the absorption of heat. Ice is melted by heat; butter melts on a warm day; iron is melted in the fierce heat of the converter. Now the ice in the freezer is melted by heat, and this heat is obtained where it can be got most readily; some from the air, some from the surrounding walls of the freezing tub which, being made of wood, which is a poor conductor, permits but little to be obtained from that direction, but principally from the relatively warm cream-sugar mixture within the

freezer. There are several other substances which could be used in place of common salt to produce this same effect, as for example calcium chlorid and ammonium chlorid; but these possess several natural disadvantages, not to speak of their greater cost, which preclude their general use.

Salt and ice

A fine salt dissolves much more rapidly than does a coarse salt, and as a result cold is more quickly produced. Its use is not common, however, for the reason that it is usually too high priced, and further that it tends to form crusts and bridges which prevent the ice from settling and fitting around the freezer. Coarse barrel salt, such as is ordinarily used for stock purposes, is satisfactory when used with caution, especially with small brine freezers, and it is considerably cheaper than the crushed rock or the ordinary flake ice cream salt. The pulverized rock salt, however, is decidedly to be preferred for packing purposes despite its higher cost, for it rattles more thoroughly through the crevices of ice, and does not melt so rapidly and thereby continues the cold for a longer time.

The ice should be broken quite fine, thus allowing more surface exposure for the action of the salt and causing more rapid freezing. Coarse lumps frequently cause trouble by cramping against the freezing can. Where it is difficult or impossible to break the ice fine, it will be found especially convenient to pour water around the freezer at the start. This tends to float the lumps and to prevent the grinding and snubbing so often noticed, especially with hand freezers. Ice that has once been used for freezing may well be used for packing purposes, but, having lost its many sharp points and edges and at times too its "specific cold," it is not as well adapted to freezing purposes as is fresh ice. White ice, *i.e.* snow ice, because of the larger amount of air which it contains, melts more slowly

than does the clear ice, and for this reason is materially better for use in packing and shipping.

Proportions of salt and ice.

The proportion 1 to 3 is frequently advocated in cook books and other similar literature, and with this statement is usually linked the recommendation that coarse salt be used. This large proportion is not found especially inconvenient in small freezers, because of the coarseness of both the salt and the ice, and the fact that a large portion of the salt does not dissolve, quantities being found later in the bottom of the freezer. Finer ice, by permitting more rapid freezing and more thorough and economical use of the salt, makes the proportion 1 to 12, 1 to 15, or even one as wide as 1 to 20 thoroughly ample, provided one-third of it be placed fully halfway from the bottom and the other two-thirds nearly on the top of the ice, so that as it dissolves it must trickle over the pieces located lower down and so do work all the way to the bottom. The application of large quantities of salt near the bottom of the freezer is very largely a waste. The proportion 1 to 15 will be found thoroughly serviceable, provided the other features have been looked after.

Duration

The duration of the freezing process, or, in other words, how long it takes, depends on the temperature of the cream and the brine, on the proportions of salt and ice which are used and upon their fineness, on the closeness of contact, and, finally, on the amount of sugar used in the cream. Sugar usage, however, is usually a nearly constant factor, and henee its effect is uniform. If the cream "mix" is placed in a common tub freezer at 60° to 65°, it requires some four to eight minutes to cool to the whipping point, and five to fifteen more to finish the freezing process. It is of course possible to cool it more quickly, in which event the cream passes through the whipping temperature so rapidly that thorough beating is impossible. If it is put into

the freezer at 34° to 36°, it may be frozen in eight to ten minutes and ample time allowed for whipping.

The rate of the melting of the ice is governed in part by the size of the salt and ice which are used. The proportions employed also affect the temperature of the freezing mixture.

Another item of procedure usually neglected, especially by small makers, is that of adding water to the salt and ice in order to hasten the freezing process. When the ice and salt are dry, a large part of the outer surface of the freezing can is exposed simply to cool air, which, as is well known, is an exceedingly poor conductor of heat. The heat contained in the cream can be effectively withdrawn only at those points where an ice fragment lies against the freezer can, here a spot and there a streak, with air circulating between, until such time as there has accumulated a sufficient amount of water from the melting of the ice to form a close fitting conductor for the heat; whereupon the cream freezes promptly. Instead of starting to freeze the cream at the temperature of 60° or 70°, as is often recommended (in cook books), in order that the ice may be melted to form water, it is much better, if it is desired to hasten the freezing process, to start with a colder cream and to pour a quart of cold water around a gallon freezer, or some two gallons around a ten-gallon freezer. This is especially true when a coarsely broken ice is used. This is the reason that ice cream so often freezes more quickly in summer than it does in winter. The addition of water thus produces a brine of the temperature of 20° to 22°. It is especially serviceable when snow is used instead of ice. To secure the best all-round results, cream that is put into the freezer at 60° to 65° should not be frozen in less than twenty minutes, and it need not require more than twenty-five; if started at 45°, from twelve to sixteen minutes are employed, while if at 34° to 35°, it may be well and smoothly frozen in eight to ten minutes; in fact the conditions are more favorable to success in the last than in the first instance.

Speed

It is very convenient in freezing ice cream to be able to use two quite different speeds. This is especially the case when it is necessary to freeze a cream which is started at ordinary room temperature, 68°. When this condition obtains, the freezer should be turned comparatively slowly when the internal fixtures have a motion equivalent to say 50 to 60 revolutions a minute for some five to eight minutes, or even much more slowly as indicated on the next page, until the temperature of the mix is below the churning point, or has reached, say, about 40°. Then the speed should be increased until the internal fixtures have a motion equivalent to about 175 to 200 revolutions a minute. This more rapid motion is necessary for the proper beating or whipping of the cream during the short time that such action can avail. If turned slowly throughout the entire process, the swell is very small and the texture coarse. If turned rapidly from the outset there is great danger of churning. The disks or other cooling apparatus of the continuous freezers which have a constant speed should be well cooled before the cream is admitted.

Cream churning in the freezer.

Not infrequently, especially when ice cream is made at home, lumps of butter form in the cream or on the dasher. This is caused by the warm, and often rich, cream being agitated too rapidly in the freezer before it has had time to cool past the churning point. If the cream is to be put in warm or at least not real cold, the turning should be relatively slow during the first eight to ten minutes. There is, furthermore, nothing to be gained by rapid turning at the outset. One revolution of the crank every half minute is ample for eight to ten minutes, or until the first indications appear of the machine laboring or running harder, at which time it will be understood that the mixture has reached that temperature where it may be whipped

and retain some of the air beaten into it. The speed should then be increased to a lively rate, which is maintained until the freezing process is nearly finished. Churning then may be avoided by less active early agitation, or by having the cream cold upon the start. The addition of water to the ice and salt may also be of value in hastening the cooling process, thus shortening the period of time when churning can take place.

The freezing point

In ordinary practice the time to stop the freezer and to remove the dasher is when the young ice cream has reached the consistency of extra heavy condensed milk. The temperature at this condition is approximately 28° to 27°. If turned long after reaching this condition, some of the air, even as much as half of that which has been previously whipped into it, will be gradually worked out, so that a much less quantity of finished product will be obtained. In this semi-liquid condition, also, it is in the best form to transfer without loss of volume.

Transferring

So far as possible all transferring and handling of the finished product should be done while it is still in a fresh condition, for it can then be managed easily and without loss, while if packed away and hardened and, later, re-dished into the pint, quart, and gallon containers, a loss of volume results. From six to six and one-half gallons of "mix," making ten gallons of finished ice cream, will fill ten gallons of orders if handled while fresh, but it will fill only nine to nine and one-half gallons of orders if dished twenty-four hours later. Taking all things into account, a loss of about 10 per cent must be expected if the ice cream is molded or packed into small containers after it has once been allowed to set.

Holding

If but a single batch of ice cream is made, it can be most easily and economically held by merely scraping the dasher, packing down the ice cream, covering the can, drawing away the water, and repacking in the freezer tub with fresh ice and salt. If more than one batch is to be run, it should be transferred as soon as convenient into cans which have previously been well cooled. If they are filled when warm and then set into the freezing vat, there will be some loss of volume, and coarse crystals of ice will form on the bottom and around the walls of the cans. If water is allowed to surround this holding can, the ice cream will harden more uniformly and more quickly, but will not become so firm as it will finally become if the water is drawn away and a fresh quantity of salt and ice is packed about it.

Re-hardening ice cream.

Ice cream that is being held and which has become weak from rising temperature should be re-hardened with great care; for if the mass has become materially melted and then is re-hardened without being run through the freezer, large water crystals will form, causing the mass to become coarse, spiny, and very unpleasant. Then, again, there is great probability that some of the skim-milk portion containing large quantities of sugar has settled to the bottom, and that the portions richer in fat have moved upwards; in which case the bottom few inches of contents will be found, when it reaches the consumer, to be but little better than a lot of sweetened ice crystals. The mass of re-hardening ice cream may be well mixed with a heavy spoon while being frozen. This procedure prevents this settling out. However, at best such re-hardened ice cream will become relatively coarse grained and spiny, and a considerable loss in volume will occur.

Re-freezing ice cream.

The taking back of melted ice cream as a practice should be most emphatically discouraged, because of the dangers which arise from the possible decomposition of the product and consequent ptomaine poisoning and from the danger of scattering contagious diseases. However, ice cream that for any reason has happened to melt while still new and fresh enough so that there is no danger of decomposition having started, may be refrozen by again placing it in the freezer and treating it as an ordinary run. This second freezing, however, requires a considerably longer time than does the initial effort, because of the air it contains; and, moreover, it is liable so to increase the amount of air contained in the cream, as to cause it to become very fluffy and weak bodied. Such thawed ice cream, if not old, may be mixed with the ordinary new "mix" and run out therewith without likelihood of this difficulty.

Butter from ice cream.

Ice cream which has melted and soured or gone "off flavor" need not he an entire loss. If such stuff is returned to the factory the butter-maker can, by mixing it with a small quantity of skim-milk and souring it yet more, churn it, and, by washing the butter rather more and salting it a little more heavily than usual, produce a butter, which, though not first class, still has market value. It would not be wise to put such a lot of ice cream, even though quite fresh, into the usual batch of cream for butter-making, for the reason that the sugar contained in the ice cream will often ferment enough to give the entire batch a sharp, unpleasant character, and the flavor used in the ice cream will cling to the butter. If the returned ice cream is quite bad, it may, if there is enough of it to pay, be churned out with the least possible amount of labor and the product sold as packing stock, eventually to find its way, with country butter which is no better, into the renovating establishments. This is one method of preventing the total loss of returned goods.

Fat-content of different portions.

It is the custom at many ice cream parlors to secure five, six, or ten gallon cans of ice cream and to hold them until they are emptied by use. Occasionally, in ease of cool weather, it requires two, three, or more days to empty them. Such conditions favor the weakening of the ice cream, because of warming.

When ice cream weakens, its fat will rise and be "dished off" to a large extent with the earlier removals from the can, so that by the time the bottom of a large can is reached, some days having elapsed, a poorer grade of ice cream is found. Pure food inspectors when drawing samples for analysis should make note of the age of the ice cream, as well as of the perpendicular location in the can whence the sample is drawn. Inasmueh as the cream can rise very little if at all even under the most favorable conditions on homogenized milk or cream, it is highly probable that no difficulty will be experienced when cream is used which has been thus modified.

Shipping

In order to secure good shipping qualities the goods should be thoroughly hardened — at about 16° F. — elear to the core for some hours before being shipped out. Otherwise the shipping ice, which should be required only to hold the ice cream from warming, is also asked to aid it in its cooling. Ice for shipping should be broken only to a medium fine grade so that it will not melt too rapidly, and it should be not too liberally provided with salt. White ice is best because it will "hold the cold."

MODIFICATION TABLE FOR USE IN MAKING APPROXIMATELY A GALLON OF ICE CREAM

Showing the approximate amounts of cream and skim-milk needed to obtain 4 lb. of fluid cream before freezing of desired grades. The figures are stated as POUNDS OR PINTS.

Quality desired	12%	15%	18%	20%	22%	25%
Material on hand to be mixed						
18% cream,	2.7	3.3	4.			
Skim-milk,	1.3	.7	.0			
20% cream,	2.4	3.	3.6	4.		
Skim-milk,	1.6	1.	.4	.0		
22% cream,	2.2	2.7	3.3	3.6	4.	
Skim-milk,	1.8	1.3	.7	.4	.0	
25% cream,	1.9	2.4	2.9	3.2	3.5	4.
Skim-milk,	2.1	1.6	1.1	.8	.5	.0
30% cream,	1.6	2.	2.4	2.7	2.9	3.3
Skim-milk,	2.4	2.	1.6	1.3	1.1	.7
35% cream,	1.4	1.7	2.1	2.3	2.5	2.8
Skim-milk,	2.6	2.3	1.9	1.7	1.5	1.2
40% cream,	1.2	1.5	1.8	2.	2.2	2.5
Skim-milk,	2.8	2.5	2.2	2.	1.8	1.5
45% cream,	1.1	1.3	1.6	1.8	2.	2.2
Skim-milk,	2.9	2.7	2.4	2.2	2.	1.8
50% cream,	1.	1.2	1.4	1.6	1.8	2.
Skim-milk,	3.	2.8	2.6	2.4	2.2	2.

NOTE. — This table may be used as follows: A 20% cream is to be frozen. One has a 35% cream on hand as well as skim-milk (whole milk may be used instead and the ice cream be none the worse and probably a good deal the better for it, if it is not made over-rich). One follows the perpendicular column headed 20% downwards until the point is reached which is on the horizontal line bearing the title

at the left "35% cream." The figures at this point show the weights (lb.) or measures (pints) of 35% cream (2.3) and skim-milk (1.7) needed to make 2 quarts or 4 pounds of a 20% cream.

Testing ice cream for fat

Carefully weigh 18 grams of a well-melted (but not overheated) and mixed sample of ice cream into a 30 per cent cream bottle. To this, add 4 or 5 c.c. of lukewarm water. Now add ordinary sulfuric acid, a little at a time, thoroughly mixing the fluids with each addition. Little more than half and seldom as much as two-thirds the usual amount of acid is required; and not more than one-half of this amount should be used at the outset, and some little time should be allowed for it to act. If the color is not yet that of strong coffee, add a little more acid, shake and pause for a time. If still the color is too light, add yet more acid. In this way the color is built up to the desired point. When the contents of the bottle have assumed almost the desired amber color, add 4 or 5 c.c. of cool water to check the further action of the acid. The test is thereafter conducted as would be an ordinary cream test, care being taken that the machine does not become too hot during whirling. If this scheme is carefully followed, particularly in the matter of the slow and gradual addition of the acid, the fat should appear in the neck of the test bottle of a clear, light brown color and distinct from the solution below. When this distinct, clean-cut condition has been obtained, the tester may feel sure, provided the work has been in other respects carried out in accord with the well-understood details of the Babcock method, that the results will be reasonably accurate.

ICE CREAM SCORE-CARDS

Several score-cards have been suggested for judging the quality of ice cream, but the work is not yet well standardized and no uniform score-card has been adopted. Baer, of the Wisconsin

Experiment Station, has suggested the following which has the desirable feature of taking the bacteria content into consideration.

THE WISCONSIN SCORE-CARD

Flavor	40
Body and texture	20
Bacteria	20
Fat	10
Appearance and color	5
Package	5
Total	100

Mortensen, of the Iowa Station, gives the following score-card and definitions:

THE IOWA SCORE-CARD

Flavor	45
Texture	25
Richness	15
Appearance	10
Color	5
Total	100

I. FLAVOR.

DEFINITION OF GOOD ICE CREAM FLAVOR

The cream flavor must be clean and creamy, and combined with flavoring material which blends with the cream to a full and delicious flavor.

DEFECTS IN FLAVOR

1. Defects due to the use of flavors which will not blend with the other ingredients.
2. Defects due to cream used:

Sour cream flavor
Old cream flavor
Bitter cream flavor
Metallic cream flavor
Oily cream flavor
Weedy cream flavor
Barn flavor
Unclean flavor
Burned or overheated flavor

3. Defects in flavor due to filler used:
   - Condensed milk flavor
   - Starch flavor
   - Gum flavor
   - Gelatine flavor
4. Defects in flavor due to other ingredients:
   - Too sweet
   - Lack of sweetness
   - Coarse flavor due to flavoring material
   - Stale fruit flavor
   - Rancid nut flavor
   - Moldy nut flavor

II. Texture.

DEFINITION OF A GOOD TEXTURE

The cream must be firmly frozen and be smooth and velvety.

DEFECTS IN TEXTURE

Icy. This defect is most noticeable toward the bottom of the container and may be due to improper packing or by holding too long ice cream which was manufactured without filler.

Coarse. This defect may be due to the use of too thin cream, or to packing while too soft.

Sticky. This is due to fillers such as gelatine, sweetened condensed milk, glucose, etc.

Buttery. This defect is due to the use of cream which has been partially churned before freezing, or to cream which enters the freezer at too high a temperature. It may also be due to operating the freezer at too high speed or to some defect in the construction of the freezer.

Too Soft. Due to improper packing after freezing.

When judging cream containing nuts, fruits, etc., due allowance should be given for the presence of such ingredients.

III. Richness.

Ice cream containing the amount of butter-fat required by the state pure food law should be considered perfect in richness.

The richness is determined by making chemical analysis for fat.

IV. Appearance.

Ice cream scoring perfect in appearance should be clean and neatly put up, and in a clean container.

Defects. — Cream of unclean appearance; lack of parchment circle

over ice cream; dirty container; rusty container; dirty ice cream tub; old tag strings attached to handle of tub.

When judging brick ice creams special attention should be given to the uniformity of the layers, to the neat folding of the parchment wrapper, and to cleanliness and general appearauce of the package.

V. Color.

Ice cream of perfect color is such as contains only the natural color imparted to it by the flavoring material used, or if color is added it should harmonize with the particular flavoring used.

Defects in Color. — Too high color; unnatural color such as colors different from the color of the natural flavoring material used.

Iudividual molds, if colored, should be as nearly as possible the same color as the object they represent.

CHAPTER XV

THE RELATION OF BACTERIA TO DAIRY PRODUCTS

THE presence of bacteria in dairy products is of great importance for the following reasons:

First. They are responsible for most of the difficulties met with in the handling of milk and the products manufactured therefrom.

Second. The making of dairy products is dependent on their action, and

Third. The presence or absence of certain types of bacteria determines the wholesomeness of dairy products for the consumer.

It may be truthfully said that the dairy industry rests on the science of bacteriology, and that nearly all the methods employed in the production and handling of these products are based on bacteriological principles. Dairy products always contain bacteria, and the success of the operator depends on his ability to control their activities.

RELATION OF BACTERIA TO MILK

Sources of bacterial contamination of milk

Interior of udder.

When milk is secreted in the udder, it is free from bacteria, but as soon as it flows into the milk ducts, it comes into contact with the organisms which always exist there. If the cow is healthy and the udder free from disease, the number of

bacteria which get into the milk at this point will be relatively small, and the species will be those which have little apparent effect on the milk, but if the cow is suffering with certain forms of disease, such as generalized tuberculosis, or if there is inflammation in the udder, the number of bacteria getting into the milk may be very large. If the udder is healthy, the milk will normally contain from a few dozen to a few hundred bacteria to a cubic centimeter at the time it is drawn from the cow. In examining 1230 samples of milk taken direct from the udders of seventy-eight cows, Harding and Wilson found an average of 428 bacteria to a cubic centimeter. The number of bacteria existing in the udder seems to be influenced somewhat by the size of the opening in the end of the teat, easy milkers having a larger number of organisms in the udder than hard milkers.

Exterior of cow's body.

The number of organisms falling into the milk pail at the time of milking will depend very largely on the cleanliness of the cow's body, the germ-content of the stable air, and the cleanliness of the milker's hands. If reasonable care is taken, the amount of contamination from these sources need not be large, but under some conditions it is very great. This is indicated by the fact that the use of a small-topped milk pail gives milk with a much lower germ-content than an open-topped pail. Harding[1] and Stocking[2] found that the use of a small-topped pail kept out more than one-half of the bacteria which normally fall into an ordinary open pail. The beneficial effect of the covered pail will vary with the cleanliness of the cow and her surroundings, but, even under the cleanest conditions, it is very marked. Certified milk-producers have long recognized this fact, and the use of a small-topped pail is one of their standard requirements.

[1] New York Experiment Station Bulletin No. 326. The Modern Milk Pail. Harding, Wilson and Smith.
[2] Storrs Experiment Station Bulletin No. 48.

The dairy utensils.

If the milk pails, strainer cloths, and other utensils with which the milk comes in contact are thoroughly cleaned and sterilized by the use of boiling water or steam, there will be practically no contamination from this source, but it has been found, under ordinary dairy conditions, that the utensils are frequently not well sterilized, and constitute one of the most important sources of contamination to the milk. This is especially true if the rinse water is allowed to stand in the pails and cans instead of their being thoroughly dried. The absolute importance of thoroughly sterilizing either with boiling water or steam, and the immediate drying of the utensils, cannot be too strongly emphasized, nor their importance overestimated in controlling the germ-content of milk.

Development of bacteria in milk

After all reasonable care has been exercised in the care of the utensils and the production of the milk, it will contain a certain number of bacteria, and the quality of the product will depend on this initial contamination and its later development.

Fresh milk exercises a certain amount of germicidal influence over the bacteria in it. The degree of germicidal action varies in the milk of different cows, and its strength and duration will depend on the temperature at which the milk is held. The influence of this action in milk is well shown by the table[1] on the following page.

Following this germicidal period, there is a more or less rapid development of the bacteria in the milk, the rate of increase depending primarily on the temperature at which the milk is held. During this period the lactic acid producing organisms (*Bact. lactis acidi*) grow very rapidly, and under normal conditions greatly outnumber the other species present, so that by

[1] Cornell Bulletin No. 197. O. F. Hunziker.

TABLE SHOWING THE GERMICIDAL ACTION IN COW'S MILK

NAME OF COW	COW WARM	TEMP.[1] OF MILK	AFTER 3 HOURS	AFTER 6 HOURS	AFTER 9 HOURS	AFTER 12 HOURS	AFTER 15 HOURS	AFTER 24 HOURS	AFTER 32 HOURS	AFTER 48 HOURS
		40°	1,080	1,220	1,040	1,020	1,120	1,360	1,040	400
May	1,212	55°	1,260	1,400	1,500	1,460	1,360	1,080	3,500	17,740
		70°	1,000	1,340	1,860	3,460	3,460	64,000	800,000	
		40°	4,400	4,260	3,620	3,700	3,900	4,000	3,900	3,840
Ida	5,120	55°	3,900	3,460	2,980	2,800	2,920	3,260	3,220	3,240
		70°	3,560	2,120	1,880	1,880	1,240	4,960	58,400	
		40°	1,170	1,070	1,120	870	1,120	990	1,060	1,080
Julia	1,345	55°	1,080	990	980	1,400	1,080	1,080	3,110	68,800
		70°	*1,000*	*1,000*	*1,200*	*5,600*	*17,720*	*1,600,000*		

the time the milk begins to sour, approximately 90 per cent of the total germ-content will consist of this type, and by the time the milk curdles, this group will usually contain 97 to 99 per cent of the entire germ-content.

The germ-content of milk at a given age will depend primarily on its original contamination and on the temperature at which it is held. Other things being equal, the lower the initial contamination, the smaller will be the resulting germ-content at any future time in the history of the milk. Since the rate at which bacteria can grow is largely dependent on temperature, the germ-content resulting from a given initial contamination will depend primarily on this factor. If milk is held at a temperature of 50 or below, bacteria grow quite slowly, but the rate of growth increases very rapidly as the temperatures rise above this point. The marked influence of temperature on the rate of growth of bacteria in milk is well illustrated by the following figures. These figures were obtained by dividing a given lot of milk and holding at the

[1] Fahrenheit.

constant temperatures of 70° F. and 50° F. until they curdled. The germ-content of each sample was obtained at each twelve-hour period.

INFLUENCE OF TEMPERATURE ON GROWTH OF BACTERIA AND KEEPING QUALITY OF MILK

	Held at 70° F.			Held at 50° F.		
Age in Hrs.	Total Number Bacteria	Acid Bacteria	Per Cent of Acid	Total Number Bacteria	Acid Bacteria	Per Cent of Acid
0	3,000	800	.19	3,000	800	.19
12	14,000	9,400	.20	1,600	800	.19
24	4,477,000	4,472,000	.21	13,500	12,800	.20
36	149,650,000	149,600,000	.26	140,800	139,400	.20
	Curdled in 99 hours.			Curdled in 315 hours.		

Changes in milk due to bacteria (see Figs. 89, 90)

In the handling of market milk, the object to be attained is the delivery of the product to the consumer in as nearly as possible the condition in which it left the udder of the healthy cow, and the problem of the producer and dealer is to prevent bacterial contamination and development. While these two factors cannot be entirely eliminated, they can be very largely controlled by methods of production and handling. Negligence at any point in the life of the milk may seriously affect the quality of the product.

The most common change in milk is its souring. This change is the result of the breaking down of the milk-sugar by the bacteria and the production of lactic acid. It can be prevented by holding the milk at low temperatures.

Occasionally the milk dealer may be annoyed by such abnormal conditions as "sweet curdling" milk, "bitter" milk,

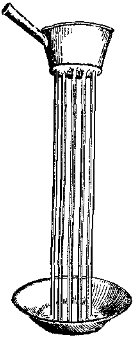


FIG. 89. — Ropy or stringy milk.

"ropy or stringy" milk. These conditions are the result of changes brought about by the growth of different species of bacteria.

The occurrence of the bitter fermentation is more common in the case of market cream than in milk. This group of bacteria gain entrance to the milk at the time of production and are able to grow at the ordinary low temperatures at which cream is held. Cleanliness at the seat of production, and thorough sterilizing of all utensils, will usually get rid of this trouble.

The occurrence of ropy or stringy milk sometimes causes serious trouble for the milk-dealer. It is caused by the growth of certain kinds of bacteria which produce a slimy, viscid condition in the milk so that it may be drawn out in fine strings or threads. While ropy milk is uot, so far as known, injurious to health, its occurrence in market milk may result in serious financial loss, because customers do not like its appearance. Outbreaks of this trouble usually occur during cool weather, because the bacteria of this group grow best at low temperatures. It is supposed that their normal habitat is water, and that they get into milk through the water used for rinsing the utensils, or by the cows wading in a stream infected with this organism, the bacteria then falling into the milk from the cow's body at

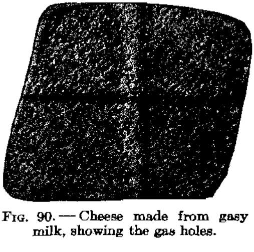


FIG. 90. — Cheese made from gasy milk, showing the gas holes.

milking time. When this trouble occurs, a thorough sterilizing of all utensils will usually be effective in getting rid of it.

Milk as a carrier of disease

It has long been known that certain diseases may be carried by milk, and the history of many milk-borne epidemics is on record.[1] Certain diseases such as tuberculosis, foot-and-mouth disease, and anthrax may be transmitted through the milk directly from a cow suffering with the disease. There is another group of diseases, such as typhoid fever, diphtheria, scarlet fever, and septic sore-throat, in which the specific organisms do not come from the cow, but get into the milk from some human source, the milk acting simply as a carrier of the organisms. Still another group of diseases, more or less indefinite in nature, but in general represented by intestinal disorders, may be caused by organisms which are carried in milk.

Of the diseases which may be transmitted directly from the cow, tuberculosis is by far the most important. The extent to which this disease is transmitted by milk to human beings is not definitely known, but the frequency with which the bovine type of tubercle bacilli has been found in children indicate that there is a considerable number of such cases. Fortunately, the tubercle bacilli do not multiply in milk, so that the number at the time the milk is consumed is no greater than when it left the cow.

Of the diseases which are transmitted from man to man by way of the milk supply, typhoid fever is the most important. The organisms which cause this disease gain entrance to the milk in a number of ways, the more important probably being direct contamination of the milk, by some person suffering with the disease or having recovered, but still carrying the organisms, or through contamination of the milk utensils by infected

[1] Bulletin 56 — Public Health and Marine Hospital Service.

water. The typhoid bacilli multiply in milk so that a small original infection may result in large numbers of organisms by the time the milk is consumed.

In the case of diphtheria and scarlet fever, the infection of the milk takes place after it has left the cow the same as in the case of the typhoid organisms. The manner of infection is similar to that of the typhoid. While epidemics of this disease which have been carried by milk are less frequent than in the case of typhoid fever, a number of cases are on record.

An epidemic disease which has more recently been traced to milk is a severe form of septic sore-throat. A number of epidemics of this disease have occurred during recent years which apparently have been definitely traced to the milk supply. Evidence up to the present time indicates that the original source of these organisms is the human throat, but they may become localized in the cow's udder, from which they may be transmitted in considerable numbers to the milk.

The group of intestinal disorders which may be carried by milk includes such troubles as are commonly known as diarrhea, summer complaint, cholera infantum, and the like. The organisms causing these troubles have not all been recognized by physicians, but it has been clearly shown that the germ-content of the milk is intimately associated with their prevalence.

While the number of epidemics of these diseases has not been large in proportion to the number of persons who consume milk, they are nevertheless of great importance, and every possible means should be taken to prevent the spreading of disease-organisms through the milk supply. There are two possible methods for accomplishing this purpose. One is to have the milk produced and handled under such sanitary conditions that danger from infection will be eliminated; the other means of protection is to treat the milk in such a way that any possible infection will be removed before the milk reaches the consumer. The first method of protection is sought in the

case of certified milk, and the success of the efforts put forth is evidenced by the record which this milk has made; but the methods necessary to safeguard milk sufficiently in this way are expensive and, under our present conditions, do not seem to be applicable to the milk supply of large cities. For such supplies, the second method, namely, the treatment of the milk after production, is doubtless the only method available at the present time. The method employed for this purpose is that known as "pasteurization," which means that the milk is heated in such a way as to kill any disease-producing organisms which may be in it. By this method the milk is heated for a definite length of time at a definite temperature.

Pasteurization of milk[1]

The value of pasteurization from a sanitary standpoint is of the greatest importance when market milk is under consideration.

In the first place, the pasteurization of milk, when the process is properly performed, affords protection from pathogenic organisms. Such disease-producing bacteria as *Bacillus tuberculosis, B. typhi, B. diphtheriæ,* and the dysentery bacillus are destroyed, or at least have lost their ability to produce disease, when heated at 140° F. for twenty minutes or more. Although the infective agent in scarlet fever is unknown, epidemics of the disease have been traced to milk supplies, and in such cases pasteurization has been resorted to as a means of safeguarding the public, with apparently satisfactory results.

In the second place, pasteurization causes a reduction of the infantile death rate due to the ordinary intestinal disturbances. Numerous experiments definitely prove the value of pasteurization in this connection. While it has not been possible to isolate any special organisms which act as the causative agents

[1] B. A. I. Circular No. 184.

n the common infantile intestinal troubles other than the one producing dysentery, it seems that high bacterial numbers in the milk consumed are associated with such diseases.

In the third place, pasteurization is of value from a commercial standpoint in so far as it increases the keeping quality of the milk and prevents financial losses caused by souring. Commercial pasteurization as practiced at the present time with reasonable care destroys about 99 per cent of the bacteria, but it does not prevent the ultimate souring of milk, although it does delay the process.

Quality of the milk to be pasteurized.

Only clean milk should be pasteurized, and it shonld never be pasteurized more than once. Dirty milk containing many millions of bacteria to a cubic centimeter is not fit for consumption, and should be condemned. Pasteurization should not be resorted to in order to make dirty milk sweet long enough to be sold or simply to pass legal regulations, but should be used only to make clean milk a safe milk.

Milk to be considered clean should be produced in barns free from manure and floating dust. The cows should be curried every day, and their flanks and udders wiped with a damp cloth just before milking. The milkers shonld wear clean suits, and their hands should be clean and dry. All milking ntensils should be cleaned and partly sterilized by steam or boiling water. After milking the milk should be removed at once to milk house to be cooled, and it should be kept cool during delivery. A farm producing milk under the above eonditions would score at least 70 points according to the score-card of the Dairy Division.

Methods of pasteurization.

Milk is pasteurized by two processes, one known as the "flash" or "continuous" process, in which the flowing milk is heated to the required temperature and held there from thirty seconds to one minute. The other is known as the "holder"

or "holding" process, and sometimes the term "held pasteurization" is applied. By the latter method the milk is held for approximately thirty minutes at the temperature desired.

The "flash" process. — The method of pasteurizing by the flash process is as follows: The milk flows from the receiving tank to the pasteurizer, where it is heated at temperatures from 160° to 165° F. for from thirty seconds to one minute. After heating it flows to the cooler, where it is cooled to from 35° to 45° F., and is then immediately bottled and placed in refrigerators at temperatures ranging from 35° to 45° until time for distribution.

The "holder" process. — The holder process is the same as the flash process, except in the temperatures used and the length of the heating period. The milk is heated in the same pasteurizer as in the flash process, but at lower temperatures — 140° to 150° F. After being heated it flows to the holding tank, where it is held for approximately thirty minutes, and is then cooled and bottled as in the flash process. The holder process possesses numerous advantages over the flash process. To insure a complete destruction of disease-producing organisms with the holder process, a temperature of 140° F. for 30 minutes is sufficient. With the flash process a temperature of 160° F. or higher is required to accomplish the same result. A much higher percentage reduction of bacteria can be obtained with the holder process than is possible with the flash process, unless very high temperatures are used, and the bacterial reductions will be more uniform in the holder process, due to the heating of all the milk to the required temperature. When using a flash machine it is often found that the percentage bacterial reduction is greatly lowered, even though the temperature is carefully maintained. Such an occurrence is due to the fact that all of the milk is not heated to the temperature indicated by the thermometer. Again, the use of the high temperatures necessary for efficient results by the flash process is objection-

able on account of the cooked taste produced in the milk, and because of the reduction of the cream line and the possibility of some chemical alteration of the milk. With the lower temperatures of the holder process no cooked taste is produced, there is no noticeable reduction of the cream liue, and only slight chemical changes, if any at all, take place. Finally, the use of lower temperatures is preferable, from a financial standpoint, as they effect a saving in the cost of steam for heating and in refrigeration for cooling.

Temperatures and methods to be used.

It is essential to use an accurate thermometer when heating milk. Many of the ordinary thermometers may register a number of degrees away from the correct reading, so the thermometer in use should be tested against a thermometer known to be correct.

As previously stated, the best method of pasteurization at the present time, and the one which should be used, is the holder process, in which the milk is held for thirty minutes. For this process a temperature of 145° F. is to be advised, since that temperature gives a margin beyond that sufficient to destroy pathogenic organisms, while at the same time it leaves in the milk the maximum number of lactic acid producing organisms which cause the souring of the milk. When using the flash process, the milk should be heated to at least 160° F. Since there is almost always a fluctuation in the temperature during pasteurization, care should be taken to see that the temperature never drops below 160° F. in the flash process.

The pasteurization of milk in bottles may, in the future, prove to be the best method when suitable machinery is devised for the process.

If the process of bottling pasteurized milk while hot proves satisfactory on a commercial scale, it will undoubtedly be an important improvement on the present system of pasteurizing milk.

Handling and delivery of pasteurized milk.

Milk after pasteurization should be cooled as rapidly as possible to 40° F. and kept at that temperature until delivery. During the warm weather it should be iced on the delivery wagons. From a sanitary standpoint all milk, whether raw or pasteurized, should be delivered as soon as possible in order to get it to the consumer in the best condition. In the best pasteurized milk there is only a slight bacterial increase when held on ice during the first twenty-four hours, yet in many cases the pasteurization and delivery may be so arranged that the consumer may get the milk before any change in the bacterial content has taken place. The cream line is, of course, regarded as an essential feature in market milk since at the present time the public demands it. It is not necessary, however, to hold milk pasteurized one morning until the next in order to get the cream line, for two or three hours' refrigeration is sufficient to get the full amount of cream. The tops of the bottles should be protected from dust, dirt, or other contamination by an overlapping cap, by a paper cover held in place by a rubber band, or by some of the patent secondary caps now on the market. The milk should be marked "pasteurized," with the date and temperature of the process. This information should be printed on the caps for the benefit of the consumer, as it is only right that he should know whether he is using raw or pasteurized milk, and if pasteurized the temperature may be of importance to him. Some persons object to using pasteurized milk, especially for infant feeding, while others desire it. It has been the experience of numerous milk dealers that the labeling of their product has greatly increased their trade.

In order to prevent all possibility of infection after the milk has been pasteurized, the process is sometimes carried on after bottling. The milk is heated by placing the bottles in a chamber where the necessary temperature can be supplied either by means of steam or hot water. The milk is then cooled by the

use of cold water or a blast of cold air. Theoretically, this method is preferable to that in which the milk is handled after it has been pasteurized, since it prevents all possible chance for recontamination. It is a newer method and not in general use, but will doubtless become more common as soon as satisfactory machinery can be developed for handling milk on a large scale.

Another phase of this general question which is of great importance to the dairyman is the protection of his herd against the spread of tuberculosis. This disease may be transmitted directly from one animal to another, or it may be carried through an infected milk supply, usually in the form of skimmed milk, buttermilk, or whey which the farmer brings back from the factory.

Pasteurization of skim-milk and whey (Farrington) [1]

It has been demonstrated that bovine tuberculosis may be carried from one herd of dairy cows to another by means of creamery skim-milk, and that a temperature of 176° F. kills the tuberculosis germs. The method of heating milk to a temperature at which disease germs will be destroyed is called pasteurization. In view of these facts, the pasteurization of skim-milk as well as buttermilk and whey becomes a matter of vital importance to the dairyman.

Four methods of pasteurizing skim-milk at creameries have been suggested:

First, by using exhaust steam from the creamery engine.

Second, by forcing steam directly from the boiler (high-pressure steam) into the skim-milk.

Third, by passing the skim-milk over a heated metal surface, as is common in the various whole-milk and cream pasteurizers now on the market.

[1] Wis. Bul. 148.

Fourth, by heating the whole milk to 176° F. and skimming it while hot, thus pasteurizing both the skim-milk and the cream in one operation.

Of the four methods suggested, the utilization of exhaust steam of the creamery engine is undoubtedly the most economical. The skim-milk is somewhat diluted by the steam and a small amount of cylinder oil from the engine also passes into it; but these additions are of little importance compared with the economy of heating in this way, as neither the small quantities of steam nor the trace of cylinder oil will affect the feeding value of the skim-milk to any appreciable extent. It is important, however, in using the exhaust steam for the pasteurization of the skim-milk to make sure that sufficient steam is obtained to heat all the milk to the desired temperature of 176° F.

Forcing high-pressure steam into skim-milk is the easiest and surest method of getting all the milk heated to the required temperature. It is a more expensive way of heating than using exhaust steam, but this is about the only objection that can be made to it.

The use of milk and cream pasteurizers which heat the skim-milk as it passes over a metal surface, which is heated either by steam or hot water, protects the skim-milk from dilution with steam, but the machines designed for pasteurizing in this way are somewhat expensive and they require more attention while in operation than the first two methods of heating.

Skimming the whole milk at a temperature of 176° F. is also expensive in the use of fuel, and further objection is made to it because of the difficulties of separating milk at this high temperature. More sediment or bowl slime accumulates in the separator when hot milk is skimmed than in the case of milk having a temperature of 80° F. The clogging of the bowl makes it necessary, therefore, to stop the machine and clean the bowl more frequently than when colder milk is skimmed;

the separator, for other reasons, requires more attention on the part of the operator when hot milk is skimmed than when skimming is done at the usual temperature.

The regenerative pasteurizers now on the market are both economical and efficient for this purpose and will undoubtedly give excellent satisfaction as milk heaters which pasteurize both the skim-milk and cream by pasteurizing the whole milk before skimming it.

Delivery of hot skim-milk.

Pasteurized milk, when cooled to near 50° F. immediately after heating, will keep sweet for a longer time than when allowed to cool gradually. Experiments have shown that pasteurized skim-milk when cooled at the creamery and delivered cold to the patrons will not keep sweet so long as when delivered hot. This is because the cans have not been sterilized after the milk is delivered at the factory; the milk left in the empty cans is sufficient to start fermentations in the cooled pasteurized skim-milk, no matter how thoroughly this has been pasteurized.

If the skim-milk is delivered to the patrons while hot, the rinsings of milk left in the cans are pasteurized by this hot skim-milk, and if it is then cooled to near 50° F. soon after heating it will keep sweet a much longer time than raw skim-milk. Cooling the cans of hot skim-milk without delay at the farm is an important factor in keeping the milk sweet. It is not sufficient to set the cans of hot skim-milk in a small tub of cold water at the farm, as this small quantity of water is warmed by the hot milk and, unless the water is changed often enough to complete the cooling, the results are unsatisfactory.

The whole milk must be sweet.

In order successfully to pasteurize skim-milk, the whole milk from which it is skimmed must be perfectly sweet; slightly sour milk is curdled by heat and will clog the pipes through which it passes.

When skim-milk is pasteurized, the transportation cans are

easily cleaned and freed from the sour milk odor which is so difficult to remove when raw skim-milk is allowed to sour in them, as is often the case.

Feeding value of pasteurized skim-milk.

Experiments have been made at several agricultural colleges to show the effect of pasteurization on the feeding value of skim-milk. Dean, of the Guelph Agricultural College, reports that "the total gain in four weeks of four calves fed pasteurized skim-milk as part of their ration was 110 lb., and of four calves fed raw skim-milk was 105 lb."

Otis, at Kansas, compared the feeding value of hand-separator skim-milk with "sterilized" creamery skim-milk and obtained the following results: Six calves were fed "sterilized" creamery skim-milk for 142 days and made an average gain a head of 250 lb. Seven calves fed the same length of time on hand-separator skim-milk made an average gain a head of 251 lb. Otis states that "at first the calves showed a dislike to the odor of the 'sterilized' skim-milk but they soon became accustomed to it and drank it readily." . . . "The hand-separator skim-milk was fed immediately after separation." . . . "Observations show that the calves receiving sterilized skim-milk were less subject to scours."

In feeding skim-milk to calves it is important that they be fed the same kind of milk all the time. It is the changing from sweet to sour or from raw to pasteurized skim-milk that is often the cause of sickness in calves.

Amount of water added to skim-milk by pasteurizing with steam.

The extent to which skim-milk is diluted by heating it with both high- and low-pressure steam (boiler and exhaust steam) was determined at our Dairy School creamery by heating a weighed quantity of skim-milk as it comes from the separator to various temperatures by forcing steam into it and weighing the hot skim-milk. The following table gives the results of these observations.

SHOWING THE EXTENT TO WHICH SKIM-MILK IS DILUTED BY PASTEURIZATION WITH STEAM

Temperature (F.) of Skim-milk		Weight of Skim-milk		Steam Pressure	Gain in Weight of Skim-milk
At separator	After heating	Before heating	After heating		
		High-pressure steam			
		Lb.	*Lb.*	*Lb.*	*Per cent*
82°	149°	50	53.2	52	6.4
83	155	50	53.5	50	7.0
86	174	50	55.0	53	10.0
88	188	50	55.5	60	11.0
		Low-pressure steam			
74	190	100	112.0	8	12.0
76	166	100	111.0	10	11.0
85	188	100	112.7	10	12.7
80	177	100	110.5	7	10.5

These figures show that the skim-milk was diluted with about 10 per cent of water when pasteurized by forcing steam into it. The exhaust steam from an engine contains more water than high-pressure steam, and skim-milk would be diluted even more than shown by the above figures when exhaust steam is used for this purpose.

Pasteurizing buttermilk

If buttermilk alone is heated to 176° F., the curd separates into a sticky mass that sinks to the bottom of the can, leaving clear whey above it. When mixed with sweet skim-milk and heated, the latter is curdled unless very small quantities of buttermilk are added.

Several attempts have been made to determine how much buttermilk may be added to skim-milk without causing it to curdle when heated. We have found that not over 5 per cent of buttermilk could be added to sweet skim-milk and the mixture heated without curdling.

No satisfactory way of pasteurizing buttermilk without separating the curd from the whey is known, but when sweet cream is pasteurized before ripening and churning there is no need of pasteurizing the buttermilk.

Tests for pasteurized milk (Hastings)

Storch's test. — The test which is usually employed by inspectors and chemists is the Storch test, named for its discoverer. Two solutions are necessary — 1st, a solution of hydrogen peroxide. This substance is sold on the market in the form of a 3 per cent solution of the pure hydrogen peroxide. For use this is diluted with 14 parts of water. This solution kept in the light gradually loses its strength, hence should be renewed at intervals of six weeks. If 0.1 per cent of sulfuric acid is added, its keeping properties will be greatly increased. The second reagent needed is an organic compound, paraphenylendiamine, a crystalline substance, colorless when perfectly fresh, but gradually decomposing and taking on a brownish color. One part of this substance is dissolved in 50 parts of hot water and the solution filtered through paper.

The test can be carried out as follows: 20 c.c. of the milk are placed in a tea cup; three to five drops of the hydrogen peroxide added, and mixed with the milk. One or two drops of the paraphenylendiamine solution is then added. In raw milk a grayish blue color develops at once, which in one-half minute changes to an indigo blue. If the milk has been heated to 176° F. or above, no color will develop immediately after the addition of the paraphenylendiamine. A color will appear in

two minutes or longer, depending upon the condition of the reagent. This test is very delicate, and in experienced hands will reveal the presence of 1 per cent of raw milk in heated milk. It is, however, open to errors and objections which should be considered. The paraphenylendiamine is difficult to procure, the solution spoils rapidly, and, when decomposed, will give a color in heated milk much resembling that given in raw milk. Again, the test cannot be used for sour milk or buttermilk unless the acidity is neutralized to a point equal to that of fresh milk. In the acid milk no color develops in the raw nor in the heated milk.

Potassium iodide-starch test. — The test recommended for general use is the potassium iodide-starch test. The hydrogen peroxide as previously described can be used, or it can be employed in the form purchased on the market (3 per cent solution). To prepare the potassium iodide-starch reagent two to three parts of wheat starch are mixed in a little cold water; 100 parts of boiling hot water are then poured over the starch, and stirred well. To this solution of starch is then added two to three parts of potassium-iodide, dissolved in a little water. The test can be carried out by placing in a tea cup 20 to 30 c.c. of the milk to be tested. Fifteen to 20 drops of the starch solution are added, and mixed with the milk. After the milk has become quiet, add one drop of the commercial hydrogen peroxide, or six to eight drops of the diluted. In raw milk a color will develop at once in the neighborhood of the drop. The color will usually be blue. Sometimes a greenish color will develop, due to the lack of sufficient potassium iodide-starch solution. The development of any color is to be looked upon as a positive test for raw milk. If the milk has been heated to 80° C. (176° F.), or above, no color will be noted on the addition of the hydrogen peroxide. The test should be read at once, and no attention paid to the development of color later, either with this test or with the paraphenylendiamine.

The advantages of the potassium iodide starch test are the cheapness and ease with which the reagents can be procured. Hydrogen peroxide is kept at every drug store and should cost not more than 50 cents a pound. Potassium iodide is a common drug. The solutions can be procured from the druggist or can be made at home. They keep well and will not need to be renewed at very frequent intervals.

The test can be applied to sweet or sour milk, buttermilk, or whey. In the case of the latter, the color is not exactly like that in milk, but is more of a greenish brown. It must be remembered that it is not the particular color that is to be noted, but the development of any color whatever.

The critical point for these tests is 176° F. Milk or other products subjected to this temperature, or higher temperatures, will not respond to the test. If the milk has been heated from 160° F. to 173–4° F., the color develops slightly more slowly than in raw milk, becoming more slow in appearance as the temperature approaches the critical point. In mixtures of raw and heated milk, the same effect is noted.

Some types of pasteurizing apparatus may fail to heat all parts of the milk to the temperature indicated by the thermometer. If any considerable portion of the milk is not being heated sufficiently high, the use of the test should reveal the same. Thus the operator will not be led into a false sense of security by relying wholly on the thermometer.

Infectious mastitis

Not infrequently dairymen have serious trouble with inflammation of the udder which may be transmitted from one cow to another. In stables where milking machines are used, this trouble sometimes becomes very serious. This form of udder inflammation is caused by certain types of bacteria which probably gain entrance through the end of the teat.

Moak[1] states that this disease may be prevented from spreading by disinfecting the teats after milking with a strong antiseptic such as pyxol, wescol, or hycol. A solution made by using a teaspoonful of disinfectant to three pints of water gave entirely satisfactory results. The method of treatment is to dip the teats in a cup containing the disinfectant immediately after milking. This treatment kills any organisms left on the teat and prevents their finding their way through the orifice into the interior of the teat. This method has proved quite satisfactory in preventing the spread of mastitis.

RELATION OF BACTERIA TO BUTTER

As already stated,[2] the commercial quality of butter is primarily dependent on the nature of the fermentation taking place in the cream, and on the by-products of bacterial activity after the butter is made. The development of acid during the cream-ripening process is the result of bacterial action, milk-sugar being converted into lactic acid. At the close of the cream-ripening process, it will contain enormous numbers of bacteria. Not infrequently, the number may be between 500,000,000 and 1,000,000,000 to a cubic centimeter. The kinds of bacteria taking part in the ripening process will very largely determine the flavor of the finished product. If the bacterial flora of the cream consists chiefly of the lactic acid organisms, the butter should have a clean, desirable flavor, but if certain other types of organisms, such as the gas-producers, are active during the ripening process, butter of inferior flavor will be quite certain to result. The purpose of the butter-maker is to control the bacteriological processes from the time the milk is received until the butter is placed on the market. If he is supplied with cream which has been produced under good sanitary conditions, he can quite accurately control the

[1] Cornell Veterinarian, April, 1916. [2] See Chapter VIII.

later fermentations, but if the cream has been produced under unsanitary conditions and miscellaneous fermentations allowed to develop, he must depend on pasteurization and the use of pure culture starters for the developing of the desired flavor in his finished butter.

Freshly made butter contains large numbers of bacteria, in spite of the fact that the larger percentage of those contained in the cream have been removed in the buttermilk and in the process of washing and working the butter.

In order that butter may keep well, it should be held at sufficiently low temperatures to prevent the rapid development of the bacteria which it contains.

Abnormal flavors.

Frequently undesirable flavors will appear in butter, seriously injuring its commercial value. Most of these "off" flavors are probably due to the action of certain kinds of bacteria in the cream, a condition known as "metallic" flavor is not uncommon, and according to Guthrie may be caused by direct absorption of metals by the cream or by the action of certain members of the *Bact. lactis acidi* group of bacteria which are able to grow in the highly acid cream. Rogers states that "fishy" flavor is caused by a slow, spontaneous chemical change to which acid is essential and which is favored by the presence of small amounts of oxygen.

Disease bacteria in butter.

If the milk and cream from which butter is made contains disease-producing bacteria, they may persist through the manufacturing process and be incorporated in the finished butter. Since so large a percentage of the bacteria in the cream are removed in the buttermilk and wash water, the danger of transmitting these diseases through butter is much less than in the case of milk. It has been shown [1] that tubercle bacilli may be

[1] Annual Report Bureau of Animal Industry, 1909, Moler, Washburn, and Rogers.

incorporated in butter and that they may retain their vitality for some time. These authors draw the following conclusions from the results of their investigations:

"The work recorded in our investigation, as well as that by contemporaneous writers, proves that constant storage in an icy temperature does not destroy the virulence of butter which contains dangerous tubercle bacilli. It should therefore be evident to all that the most satisfactory way of obviating this danger would be to manufacture butter only from cream that is free from tubercle bacilli. The application of the tuberculin test to all cows that supply milk for butter-making purposes, with the subsequent removal of all tuberculous animals from these dairy herds, is desirable, but where this cannot be done recourse may be had to pasteurization, as it has been found that subjecting cream to a temperature of 140° F. (60° C.) for a period of twenty minutes, or of 176° F. (80° C.) momentarily, will effectually destroy all of the tubercle bacilli that may have found lodgment in it. Moreover, the manufacture of butter out of pasteurized cream has other advantages, as set forth in Bureau of Animal Industry Circular 146.

"No dependence should be placed on the action of the salt that is added to butter as an agent in the destruction of tubercle bacilli. It has been shown that the effect of salt as commonly used in the manufacture of butter is very slight at best. Most of the samples of butter used in the present experiments were salted with the usual amount, yet the butter retained its virulence for six months, as already noted."

As a safeguard against the transmission of disease through butter, it is the common practice in creameries at the present time thoroughly to pasteurize the cream from which butter is made. This practice serves not only as a protection against the transmission of disease, but at the same time gives butter of more uniform quality.

RELATION OF BACTERIA TO CHEESE

The action of bacteria in the processes of cheese-making and ripening is much more complex than in the case of butter. The quality of the cheese is dependent on the sanitary quality and bacterial flora of the milk from which it is made, and, as in the ripening of cream for butter, so in the ripening of milk for cheese, the prime essential is to favor the development of the lactic acid bacteria while holding other kinds in check. If the milk is clean and undergoes the proper lactic fermentation during the ripening process, there should be little difficulty in developing the desired flavor and texture during the curing process, but if the original milk contains gas-producing bacteria, yeasts or oidium lactis, it will be difficult to develop a cheese of high quality.

Many theories regarding the changes which take place during cheese ripening have been advanced, and much research work has been done in recent years both from the chemical and biological standpoint. While large numbers of the bacteria in the milk pass out in the whey, large numbers are also left in the curd and, these being held at warm temperatures during the cheddaring process, develop with enormous rapidity. It has been found that fresh cheese may contain more than 1,000,000,000 bacteria to a gram, and it has been shown that these play an important part in the later ripening of the cheese. It has also been shown that the enzymes normal to milk and in the rennet extract are factors in the ripening process.

In the ripening of the different groups of fancy cheeses, special organisms are responsible for the flavor and texture of the ripened cheese. In such cheeses as the Roquefort, Gorgonzola, and Stilton, in addition to the action of the lactic acid organisms, the special flavor is developed by the growth of certain kinds of molds through the cheese. In the case of Limburger, the ripening of the cheese is caused by the enzymes

produced by the growth of bacteria on the surface of the cheese, while in such cheeses as the Camembert, the curd is ripened by the enzymes produced by the growth of the white mold on the surface, while the flavor is due to the combined action of the lactic acid bacteria and oidium lactis.

Disease organisms in cheese.

But little work has been done regarding the presence of disease bacteria in market cheese. Harrison[1] conducted a series of experiments to determine the length of time the tubercle bacilli would persist in cheddar cheese. He made a series of cheeses from milk specially inoculated with cultures of tubercle bacilli, which were tested at intervals by inoculation experiments with small animals. As a result of his experiments, he concludes as follows:

"If cheddar cheese as commonly made in the United States and Canada happens to contain tubercle bacilli naturally present, it may be assumed that none of these germs will be living when the cheese becomes ten weeks old. Hence, no danger need be apprehended of acquiring the disease known as *consumption* by eating well-cured cheddar cheese."

Mahler, Washburn, and Doane,[2] after reviewing the experimental work on this subject, draw the following conclusions:

"As a result of these various experiments it is evident that the bacillus of tuberculosis not only retains its life but also its virulence in cheese for a considerable period in time, and that cheese made from raw, unpasteurized milk should therefore be considered as a possible carrier of tubercle bacilli.

"Knowing that there are many tuberculous cows among the dairy herds which furnish milk for the manufacture of cheese in this country, it is evident that some steps should be taken to prevent the introduction of living, virulent tubercle bacilli into this important food product. The best possible means to

[1] Annual Report Bureau Animal Industry, 1902.
[2] Annual Report Bureau Animal Industry, 1909.

this end would be the removal of all tuberculous cattle from the dairy herds of the country. This, however, is a proposition of such magnitude that its early accomplishment is a practical impossibility, and some other and more feasible method of rendering the products of our cheese factories more wholesome must therefore be found. If it be possible to use pasteurized milk in the manufacture of cheese without injuring the product, a simple solution of the problem is offered to the cheese manufacturers in the process known as pasteurization. Abundant proof has been furnished to establish the fact that whenever milk is heated to 140° F. (60° C.) and held at that temperature for twenty minutes, or heated to 176° F. (80° C.) momentarily, all of the tubercle bacilli which it may contain are destroyed and the product obtained from it is rendered safe and wholesome."

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